

THE PROGRAM



BERLIN 2012



MAPS - TRAFFIC - NAVIGATION

Approved by TÜV SÜD Germany: "TomTom HD Traffic provides the best quality of traffic information" Prof. Michael Schreckenberg, University of Duisburg-Essen "TomTom's HD Traffic is in a league of its own."

TomTom Quiz

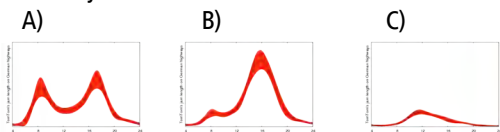
Win a prize!

See us at our TomTom Minisymposium on Wed, 22 Aug, 13:15-14:45, H104

Suche Straße Des 17. Juni 135| Berlin, DE

- How many navigable road kilometers do TomTom maps cover worldwide?
 - 34.8 million
 - 42.0 million
 - 68.9 million
- What is the total length of the entire Berlin road network?
 - 5,200 km
 - 6,300 km
 - 7,400 km
- What was the total distance travelled in Berlin by TomTom users reporting anonymously speed data from January until March 2012?
 - 2,483,178 km
 - 5,205,726 km
 - 7,738,423 km
- How many traffic jams does TomTom HD Traffic detect and broadcast in a typical afternoon rush hour in Berlin?
 - 26
 - 85
 - 120
- How long did an average driver with a daily commute of 30 minutes free-flow travel time spend in traffic jams in Berlin in 2011?
 - 35 hours
 - 69 hours
 - 83 hours
- In which hour of the week is traffic slowest going west on Straße des 17. Juni in front of the TU Berlin main building?
 - Mondays @ 17:00-18:00
 - Tuesdays @ 17:00-18:00
 - Fridays @ 16:00-17:00

7. The plots below show average jam lengths (Y-axis) over time (X-axis) on the entire German Autobahn network. Which one of the plots depicts a Thursday, which one a Friday and which one a Saturday?



Quiz forms can be found in the conference bag. Quiz results will be announced at the TomTom Minisymposium Wednesday, 22 Aug, 13:15-14:45

ISMP 2012

21st International Symposium on Mathematical Programming

August 19–24, 2012 · Berlin, Germany

Program committee

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- Gérard Cornuéjols
Carnegie Mellon University
- Friedrich Eisenbrand
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- Madeleine Theile
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WELCOME TO ISMP 2012

On behalf of the ISMP 2012 Organizing Committee, the Technische Universität Berlin, and the Mathematical Optimization Society, I welcome you to ISMP 2012, the 21st International Symposium on Mathematical Programming.

The symposium covers all theoretical, computational, and practical aspects of mathematical optimization. With roughly six-hundred invited and contributed sessions, fifteen invited state-of-the-art lectures, five history lectures, totaling well over seventeen-hundred presentations, this is by far the largest ISMP so far. Roughly two-thousand participants from more than sixty countries all over the world will learn about the most recent developments and results and discuss new challenges from theory and practice. These numbers are a clear indication of the importance of Mathematical Optimization as a scientific discipline and a key technology for future developments in numerous application areas.

Berlin is an exciting city that has experienced dramatic political, economical and social changes within the past 25 years. The opening ceremony of ISMP 2012 will take place at the Konzerthaus on the historic Gendarmenmarkt which is considered one of the most beautiful squares in Europe. The conference dinner will take place at the Haus der Kulturen der Welt (“House of the Cultures of the World”) located in the Tiergarten park with a beer garden on the banks of the Spree river and a view on the German Chancellery. I hope that you will also find the time to take a look around Berlin on your own, to obtain a feeling for the vibrant life style, and to explore the many attractions of this wonderful city.

Finally, I would like to express my sincere appreciation to all of the many volunteers who made this meeting possible. I wish to acknowledge, in particular, the members of the program committee, the cluster chairs, and the many session organizers for setting up the scientific program. My sincere thanks go to the members of the organizing committee and everyone involved in the local organization – the system administrators, secretaries, student assistants, PhD students, and postdocs – for the many days, weeks and even months of work.

I wish you all an enjoyable and memorable ISMP 2012 in Berlin.

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THE OPENING CEREMONY

The opening ceremony takes place on Sunday, August 19, 18:00, at the “Konzerthaus am Gendarmenmarkt”.

Chair: Günter M. Ziegler

Musical accompaniment: Berliner Sibelius Orchester

Conducted by Vinzenz Weissenburger

Welcome addresses

- Martin Skutella
(Organizing Committee Chair)
- Nicolas Zimmer
(Permanent Secretary for Economics, Technology and Research of the State of Berlin)
- Paul Uwe Thamsen
(First Vice President of the Technische Universität Berlin)
- Philippe Toint
(Chair of the Mathematical Optimization Society)

Awards

- *Dantzig Prize* for original research which by its originality, breadth and depth, is having a major impact on the field of mathematical optimization
- *Lagrange Prize* for outstanding works in the area of continuous optimization
- *Fulkerson Prize* for outstanding papers in the area of discrete mathematics
- *Beale-Orchard-Hayes Prize* for excellence in computational mathematical programming
- *Tseng Lectureship* for outstanding contributions in the area of continuous optimization, consisting of original theoretical results, innovative applications, or successful software development
- *Tucker Prize* for an outstanding doctoral thesis: Announcement of the three finalists

Reception

The opening ceremony is followed by a reception with a magnificent view on Gendarmenmarkt.

OVERVIEW OF EVENTS

Registration

- Sunday, August 19, 15:00–18:00
Konzerthaus Berlin
(Gendarmenmarkt, 10117 Berlin)
- Monday, August 20, 07:00–18:30
Main Building of TU Berlin
(Straße des 17. Juni 135, 10623 Berlin)
- Tuesday through Friday, August 21–24, 7:30 – 18:30
Main Building of TU Berlin
(Straße des 17. Juni 135, 10623 Berlin)
- From Monday through Friday, the central activities like registration etc. will take place in the Main Building of the TU Berlin (Straße des 17. Juni 135). The conference office and the information desk are located in the lobby of the Main Building.
For a detailed map of the campus and the buildings please see page 25.
- Airport Registration Service: From Friday, August 17, 14:00, through Sunday, August 19, 16:00, ISMP 2012 would like to welcome you at the Berlin airports TXL and SXF.
Find more details on how to obtain this service on the ISMP 2012 webpage (<http://ismp2012.mathopt.org>).

Opening Ceremony and Reception

Sunday, August 19, 18:00, at the Konzerthaus am Gendarmenmarkt, featuring symphonic music by the Berliner Sibelius Orchester; followed by a reception with beverages and some fingerfood (see 3).

Please consult the *ISMP Berlin Guide* for instructions on how to get to the Konzerthaus.

Awards

During the opening ceremony, the following prizes will be awarded: Dantzig Prize, Lagrange Prize, Fulkerson Prize, Beale-Orchard-Hayes Prize, and Tseng Memorial Lectureship. Moreover, the Tucker Prize finalists will be announced.

The Tucker Prize will be awarded during the Tucker Prize Session on Monday at 10:30 in room MA 041 (Math Building) followed by presentations by the finalists.

The Tseng Memorial Lecture will take place on Tuesday at 17:00 in room H 0105 (Main Building).

Plenary and Semi-Plenary Lectures

Featured state-of-the-art lectures are given by 15 distinguished speakers. (See page 8.)

Historical Lectures

Five special history lectures are scheduled reporting on work of Euler, Leibniz, Weierstrass, Minkowski, and the inventor of the electronic computer Konrad Zuse. (See page 16.)

Parallel Sessions

More than 1700 talks are given in almost 600 invited and contributed sessions. See program on page 30 and, in more detail, on page 74

All alterations in the scientific program and other important information for participants will be announced on a message board near the information desk in the lobby of the Main Building.

Conference Dinner

The conference dinner will take place on Wednesday, August 22, 19:00, at the Haus der Kulturen der Welt (“House of the Cultures of the World”) located in the Tiergarten park with a beer garden on the shores of the Spree river and a view on the German Chancellery.

Tickets are 40 € and can be purchased at the ISMP registration desk.

Please consult the *ISMP Berlin Guide* for instructions on how to get to the Haus der Kulturen der Welt.

Receptions

- Monday, August 20, 18:00
Informal welcome reception at TU Berlin with soft drinks, beer and pretzels.
- Friday, August 24, 18:00
Farewell gathering at TU Berlin with beverages and snacks.

MOS Business Meeting

The business meeting of the Mathematical Optimization Society (MOS) will take place on Tuesday, August 21, at 18:15 in room H 0105.

REGISTRATION AND GENERAL INFORMATION

Registration. Your registration fee includes admittance to the complete technical program and most special programs.

The following social/food events are also included: Opening ceremony including reception on Sunday evening, welcome reception on Monday evening, farewell gathering on Friday evening, and all morning and afternoon coffee breaks.

The Wednesday evening conference dinner requires a separate payment of 40 €.

Badges required for conference sessions. ISMP badges must be worn at all sessions and events. Attendees without badges will be asked to go to the registration desk to register and pick up their badges.

All attendees, including speakers and session chairs, must register and pay the registration fee.

Conference dinner tickets. The Wednesday evening conference dinner is open to attendees and guests who registered and paid in advance for tickets. The tickets are included in your registration envelope. There may be a limited number of tickets available on site. Go to the ISMP registration desk to inquire. Tickets are 40 €.

Questions and information. The organizers, staff of the conference desk, and the student assistants will be identifiable by colored name tags and orange T-shirts. Please contact them if you have any questions.

Do not hesitate to inquire about all necessary information concerning the conference, orientation in Berlin, accommodation, restaurants, going out, and cultural events at the information desk which is located in the lobby of the Main Building.

Getting around by public transport. The conference badge allows you to use all public transport in and around Berlin (zone ABC) during the symposium from August 19 to August 24. In order to identify yourself, you need to carry along your passport or national ID card. Please refer to the *ISMP Berlin Guide* for more information on public transport in Berlin.

Messages. The best way for people to reach you is to contact you directly at your hotel. Please leave your hotel phone number with your colleagues and family members. For urgent messages, call the ISMP registration desk: +49 (0)30 314 21000. Registration staff will transcribe the message and post it on the message board located near registration.

You can also contact colleagues attending the meeting using this message board. Please check the board periodically to see if you have received any messages.

Internet access. If your home university participates in eduroam and you have an account, you can directly connect to eduroam WiFi at TU Berlin.

Otherwise, for using the WiFi network in the TU Berlin, eduroam guest accounts will be provided to you. You will receive the username and password with your registration. To access the WiFi network, you will need to install certificates to connect to eduroam which can be found on the ISMP USB flash drive or downloaded at the first login. In case of problems, please contact the WiFi helpdesk which is located in the lobby of the Main Building.

Snacks and coffee breaks. Coffee, tea, and beverages are served during all breaks in the Main Building (H) and the Mathematics Building (MA). Moreover, various cafeterias are located in the Main Building (H) and Mathematics Building (MA).

Food. The Mensa of the TU Berlin offers plenty of opportunities for lunch at moderate prizes. In the vicinity of the TU Berlin, there are also many different restaurants from fast food to gourmet restaurants. For the daily lunch break, please consult the *Restaurant Guide* (leaflet) for a list of nearby cafeterias and restaurants. Moreover, a selection of nice restaurants, cafés, pubs, bars etc. in different neighborhoods of Berlin can be found in the *ISMP Berlin Guide*.

You find both guides in your conference bag and on the ISMP USB flash drive.

Cloakroom. Participants are asked to look carefully after their wardrobe, valuables, laptops and other belongings for which the organizers are not liable. You will find a cloakroom in the Main Building.

ISMP Berlin Guide. You want to experience Berlin as Berliners do? Valuable information that you might find useful during your stay can be found in the *ISMP Berlin Guide* in your conference bag and on the ISMP USB stick. Getting around, sightseeing, and going out are some of the topics covered. And, of course, you can find a great collection of restaurants, cafés, bars, pubs etc.

SOCIAL PROGRAM

Monday, August 20, 14:00–16:00

Discover the historic heart of Berlin

Every street in the center of Berlin has history, much of it no longer visible: On this walk you will meet the ghosts and murmurs of Prussians and Prussian palaces, Nazis and Nazi architecture, Communists and real, existing socialist architecture, as well as visit some sites of the present.

Meetingpoint: Book store "Berlin Story", Unter den Linden 40 (near S 'Unter den Linden', Bus 100, 200).

Tickets: 15 EUR

Groupsize: min 5; max 25

Booking Deadline: August 13

Pre-booking requested at info@stattreisenberlin.de

Tuesday, August 21, 14:00–16:00

Where was the Wall

Berlin:the heart of the cold war. So little is left. Walking the former "deathstrip" between Checkpoint Charlie and Potsdam Square, listen to the stories of how a city was violently split in 1961, how one lived in the divided city, how some attempted to escape from the east, how the wall fell in 1989, and memory today.

Meetingpoint: Underground Station Stadtmitte, on the platform of the U6 (not of the U2!). End: Potsdamer Platz

Tickets: 15 EUR

Groupsize: min 5; max 25

Booking Deadline: August 13

Pre-booking requested at info@stattreisenberlin.de

Wednesday, August 22, 14:00–16:00

Where was the Wall

Berlin:the heart of the cold war. So little is left. Walking the former "deathstrip" between Checkpoint Charlie and Potsdam Square, listen to the stories of how a city was violently split in 1961, how one lived in the divided city, how some attempted to escape from the east, how the wall fell in 1989, and memory today.

Meetingpoint: Underground Station Stadtmitte, on the platform of the U6 (NOT of the U2!) End: Potsdamer Platz

Tickets: 15 EUR

Groupsize: min 5; max 25

Booking Deadline: August 13

Pre-booking requested at info@stattreisenberlin.de

Thursday, August 23, 14:00–16:00

Potsdam – Residence of Frederic the Great

To many outside Germany Potsdam, where the Prussian Kings lived, symbolized Prussia; one spoke of a battle between Potsdam and Weimar for the German soul. But what was Potsdam really? A city of the military, certainly, but also a city of immigrants; a city defined by the court, yes, but also much, more.

Meetingpoint: Potsdam, Alter Markt, Obelisk, close to Potsdam-Hauptbahnhof (S7; RB)

Tickets: 18 EUR

Groupsize: min 5; max 25

Booking Deadline: August 13

Pre-booking requested at info@stattreisenberlin.de

For the booking of further individual tours you may check the website of the tour operator StattReisen Berlin GmbH at www.stattreisenberlin.de.

You can book most of the tours in various languages for mini groups from 120 EUR.

SPEAKER AND CHAIR INFORMATION

Speaker guidelines

Audio-visual services. All session rooms will be equipped with a computer projector with VGA input. Please follow these guidelines to ensure a successful presentation:

- Please bring your laptop to your session. We strongly recommend that you pre-arrange with other speakers in your session to ensure that at least one of you brings a laptop which can be connected to the computer projector.
- Please bring a power adapter which can be connected to the German grid. We recommend that you do not attempt to run your presentation off the laptop battery.
- If your notebook does not provide a standard VGA port to connect to the beamer, please have the required adapter at hand (e.g., Mini DisplayPort or dvi to VGA).
- Please arrive at your session at least 15 minutes before it begins. All presenters in a session should set up and test the connection to the projector before the session begins.
- We encourage speakers to have at hand a USB flash drive with a copy of their presentation.
- If you need an overhead projector for your talk, please contact the registration office on arrival. Overhead projectors will only be available in exceptional cases.

Presentation guidelines. The room and location of your session are listed on page 30 ff. and in detail on page 74 ff. Please arrive at your session at least 15 minutes early for technical set-up and to check in with the session chair.

Time your presentation to fit within the designated time span of 25 minutes, leaving enough time for audience questions and change of speaker.

There will be a speakers' preparation room available in the Main Building in room H 1036. Student assistants will provide support for the handling of the computer projectors.

Program information desk. If you have general questions about the meeting or questions about your own presentation, stop by at the Program Information Desk located in lobby of the Main Building. We ask Session Chairs to notify the Information Desk about any last-minute changes or cancellations; these changes will be posted outside the meeting rooms.

Assistance during your session. If you have a problem in your session room related to technical needs or any other requests, please contact one of the student assistants wearing an orange T-shirt.

Session chair guidelines

The role of the Chair is to coordinate the smooth running of the session and introduce each speaker. The chair begins and ends each session on time. Each talk lasts 25 minutes plus 5 minutes for discussion and change of speaker. Please stick to the order of talks and times announced in the program.

PLENARY AND SEMI-PLENARY LECTURES: Monday

Plenary lecture

Mon.09:00.H0105

Rakesh V. Vohra

Polymatroids and auction theory

Chair John Birge

A polymatroid is a polytope associated with a submodular function. Its not often one can write a sentence that contains at least three words designed to scare small animals and little children, but there it is. Polymatroids will be familiar to students of optimization because of their attractive properties. Less well known is that these useful creatures are to be found lurking in the roots of auction theory. In this talk, I will describe how they arise and give examples of why they are useful in auction theory.

[Rakesh Vohra](#) is the John L. & Helen Kellogg Professor of Managerial Economics and lapsed math programmer. He occupies himself with the usual obligations of a faculty member ... sitting and thinking and, when required, standing and professing. He thinks mostly about pricing, auctions and the design of markets. He professes on the same but with less success.

Semi-plenary lecture

Mon.17:00.H0105

Dimitris Bertsimas

A computationally tractable theory of performance analysis in stochastic systems

Chair Friedrich Eisenbrand

Modern probability theory, whose foundation is based on the axioms set forth by Kolmogorov, is currently the major tool for performance analysis in stochastic systems. While it offers insights in understanding such systems, probability theory is really not a computationally tractable theory. Correspondingly, some of its major areas of application remain unsolved when the underlying systems become multidimensional: Queueing networks, network information theory, pricing multi-dimensional financial contracts, auction design in multi-item, multi-bidder auctions among others. We propose a new approach to analyze stochastic systems based on robust optimization. The key idea is to replace the Kolmogorov axioms as primitives of probability theory, with some of the asymptotic implications of probability theory: the central limit theorem and law of large numbers and to define appropriate robust optimization problems to perform performance analysis. In this way, the performance analysis questions become highly structured optimization problems (linear, conic, mixed integer) for which there exist efficient, practical algorithms that are capable of solving truly large scale systems. We demonstrate that the proposed approach achieves computationally tractable methods for (a) analyzing multiclass queueing networks, (b) characterizing the capacity region of network information theory and associated coding and decoding methods generalizing the work of Shannon, (c) pricing multi-dimensional financial contracts generalizing the work of Black, Scholes and Merton, (d) designing multi-item, multi-bidder auctions generalizing the work of Myerson. This is joint work with my doctoral student at MIT Chaithanya Bandi.

[Dimitris Bertsimas](#) is currently the Boeing Leaders for Global Operations Professor of Management and the co-director of the Operations Research Center at the Massachusetts Institute of Technology. He has received a BS in Electrical Engineering and Computer Science at the National Technical University of Athens, Greece in 1985, a MS in Operations Research at MIT in 1987, and a PhD in Applied Mathematics and Operations Research at MIT in 1988. Since 1988, he has been in the MIT faculty. His research interests include optimization, stochastic systems, data mining, and their applications. In recent years he has worked in robust optimization, health care and finance. He is a member of the National Academy of Engineering and he has received several research awards including the Farkas prize, the SIAM Optimization prize and the Erlang Prize.

Tuesday

Semi-plenary lecture

Mon.17:00.H0104

Katya Scheinberg

Using randomized models in black-box and derivative free optimization

Chair Luís Nunes Vicente

All derivative free methods rely on sampling the objective function at one or more points at each iteration. Direct search methods (developed by Dennis, Torczon, Audet, Vicente and others) rely on sample sets of defined configuration, but different scales. Model-based DFO methods (developed by Powell, Conn, Scheinberg, Toint, Vicente, Wild and others) rely on building interpolation models using sample points in proximity of the current best iterate. Constructing and maintaining these sample sets has been one of the most essential issues in DFO. Many of the existing results have been summarized in a book by Conn, Scheinberg, Vicente, where all the sampling techniques considered for deterministic functions are deterministic ones. We will discuss the new developments for using randomized sampled sets within the DFO framework. Randomized sample sets have many advantages over the deterministic sets. In particular, it is often easier to enforce “good” properties of the models with high probability, rather than the in the worst case. In addition, randomized sample sets can help automatically discover a good local low dimensional approximation to the high dimensional objective function. We will demonstrate how compressed sensing results can be used to show that reduced size random sample sets can provide full second order information under the assumption of the sparsity of the Hessian. We will discuss new convergence theory developed for the randomized models where we can, for instance, show that as long as the models are “good” with probability more than $\frac{1}{2}$ then our trust region framework is globally convergent with probability 1 under standard assumptions.

[Katya Scheinberg](#) is an associate professor in the Industrial and Systems Engineering Department at Lehigh University. A native from Moscow, she earned her undergraduate degree in operations research from the Lomonosov Moscow State University in 1992 and then received her PhD in operations research from Columbia in 1997. Scheinberg was a Research Staff Member at the IBM T. J. Watson Research center for over a decade, where she worked on various applied and theoretical problems in optimization, until moving back to Columbia as a visiting professor in 2009 and later on to Lehigh. Her main research areas are related to developing practical algorithms (and their theoretical analysis) for various problems in continuous optimization, such as convex optimization, derivative free optimization, machine learning, quadratic programming, etc. Scheinberg has also published a book in 2008 titled, *Introduction to Derivative Free Optimization*, which is co-authored with Andrew R. Conn and Luis N. Vicente. She is currently the editor of *Optima*, the MOS newsletter, and an associate editor of *SIOPT*.

Plenary lecture

Tue.09:00.H0105

Robin Thomas

A new look at excluding a non-planar graph

Chair Gérard Cornuéjols

At the heart of the Graph Minors project of Robertson and Seymour lies a deep theorem saying that every graph G with no minor isomorphic to a fixed graph H has a certain structure. The structure can then be exploited to deduce far-reaching consequences. The exact statement requires some explanation, but roughly it says that there exists an integer k depending on H only such that G has a tree-decomposition into pieces, each of which has a k -near embedding in a surface S that does not embed H . Here a k -near embedding means that after deleting at most k vertices the graph can be drawn in S without crossings, except for k local areas of non-planarity, where crossings are permitted, but the graph is constrained in a different way, again depending on the parameter k . I will explain the theorem and its applications, and then will discuss recent work: a much simpler proof and a variation on the theorem, which adds some restrictive assumptions, but is much easier to state and to apply. Part of this is joint with Ken-ichi Kawarabayashi and Paul Wollan, and part is joint with Sergey Norin.

[Robin Thomas](#) received his PhD from Charles University in Prague, formerly Czechoslovakia, now the Czech Republic. He has worked at the Georgia Institute of Technology since 1989. Currently he is Regents' Professor of Mathematics and Director of the multidisciplinary PhD program in Algorithms, Combinatorics, and Optimization. In 1994 and 2009 he and his coauthors won the D. Ray Fulkerson prize in Discrete Mathematics.

Tuesday

Tseng memorial lecture lecture

Tue.17:00.H0105

TBA

Tseng memorial lectureChair [Sven Leyffer](#)

This lecture will be given by the prize winner of the Tseng Memorial Lectureship. The prize was established in 2011 and will be awarded for the first time during the opening ceremony of ISMP 2012.

Semi-plenary lecture

Tue.17:00.H1058

[Rekha R. Thomas](#)**Lifts and factorizations of convex sets**Chair [Martin Skutella](#)

A basic strategy for linear optimization over a complicated convex set is to try to express the set as the projection of a simpler convex set that admits efficient algorithms. This philosophy underlies all lift-and-project methods in the literature which attempt to find polyhedral or spectrahedral lifts of complicated sets. Given a closed convex cone K and a convex set C , there is an affine slice of K that projects to C if and only if a certain “slack operator” associated to C can be factored through K . This theorem extends a result of Yannakakis who showed that polyhedral lifts of polytopes are controlled by the non-negative factorizations of the slack matrix of the polytope. The connection between cone lifts and cone factorizations of convex sets yields a uniform framework within which to view all lift-and-project methods, as well as offers new tools for understanding convex sets. I will survey this evolving area and the main results that have emerged thus far.

[Rekha Thomas](#) received a PhD in Operations Research from Cornell University in 1994 under the supervision of Bernd Sturmfels. After holding postdoctoral positions at the Cowles Foundation for Economics at Yale University and ZIB, Berlin, she worked as an assistant professor of Mathematics at Texas A&M University from 1995–2000. Since 2000, she has been at the University of Washington in Seattle where she is now the Robert R. and Elaine F. Phelps Endowed Professor of Mathematics. Her research interests are in optimization and computational algebra.

Wednesday

Semi-plenary lecture

Tue.17:00.H0104

Teemu Pennanen

Introduction to convex optimization in financial markets

Chair John Birge

Convexity arises quite naturally in financial risk management. In risk preferences concerning random cash-flows, convexity corresponds to the fundamental diversification principle. Convexity is a basic property also of budget constraints both in classical linear models as well as in more realistic models with transaction costs and constraints. Moreover, modern securities markets are based on trading protocols that result in convex trading costs. This talk gives an introduction to certain basic concepts and principles of financial risk management in simple optimization terms. We then review some convex optimization techniques used in mathematical and numerical analysis of financial optimization problems.

[Teemu Pennanen](#) is the Professor of Mathematical Finance, Probability and Statistics at King's College London. Before joining KCL, Professor Pennanen worked as Managing Director at QSA Quantitative Solvency Analysts Ltd, with a joint appointment as Professor of Stochastics at University of Jyväskylä, Finland. His earlier appointments include a research fellowship of the Finnish Academy and several visiting positions in universities abroad. Professor Pennanen's research interests include financial risk management, financial econometrics, mathematical finance and the development of computational techniques for risk management. He has authored more than 30 journal publications and he has been a consultant to a number of financial institutions including Bank of Finland, Ministry of Social Affairs and Health and The State Pension Fund.

Plenary lecture

Wed.09:00.H0105

Christof Schütte

Optimal control of molecular dynamics using Markov state models

Chair Martin Skutella

Molecular systems exhibits complicated dynamical behavior that is responsible for its (biological or nanotechnological) functionality. The effective dynamics can be characterized by the switching behavior between several metastable states, the so-called conformations of the system. Therefore, steering a molecular system from one conformation into another one means controlling its functionality. This talk considers optimal control problems that appear relevant in molecular dynamics (MD) applications and belong to the class of ergodic stochastic control problems in high dimensions. It will be demonstrated how the associated Hamilton-Jacobi-Bellman (HJB) equation can be solved. The main idea is to first approximate the dominant modes of the MD transfer operator by a low-dimensional, so-called Markov state model (MSM), and then solve the HJB for the MSM rather than the full MD. The approach rests on the interpretation of the corresponding HJB equation as a nonlinear eigenvalue problem that, using a logarithmic transformation, can be recast as a linear eigenvalue problem, for which the principal eigenvalue and the associated eigenfunction are sought. The resulting method will be illustrated in application to the maximization of the population of alpha-helices in an ensemble of small biomolecules (Alanine dipeptide).

[Christof Schütte](#) is a professor in the Mathematics and Computer Science Department at Freie Universität Berlin (FU). He holds a diploma in physics from Paderborn University and a PhD in mathematics from FU. Since 2008, he is the co-chair of the DFG Research Center MATHEON in Berlin and the head of the Biocomputing Group at FU. Christof gave a plenary lecture at ICIAM 2007 in Zurich and was an invited speaker at the 2010 International Congress of Mathematicians in Hyderabad. His research is on modeling, simulation and optimization in the life sciences with a special focus on stochastic multiscale problems in molecular and systems biology and on information-based medicine. He is currently the head of the Innovation Laboratory "Math for Diagnostics" in Berlin.

Semi-plenary lecture

Wed.17:00.H0104

Claudia Sagastizábal

Divide to conquer: Decomposition methods for energy optimization

Chair Alejandro Jofré

Modern electricity systems provide a plethora of challenging issues in optimization. The increasing penetration of low carbon renewable sources of energy introduces uncertainty in problems traditionally modeled in a deterministic setting. The liberalization of the electricity sector brought the need of designing sound markets, ensuring capacity investments while properly reflecting strategic interactions. In all these problems, hedging risk, possibly in a dynamic manner, is also a concern. The fact of representing uncertainty and/or competition of different companies in a multi-settlement power market considerably increases the number of variables and constraints. For this reason, usually a trade-off needs to be found between modeling and numerical tractability: the more details are brought into the model, the harder becomes the optimization problem. Both for optimization and generalized equilibrium problems, we explore some variants of solution methods based on Lagrangian relaxation and on Benders decomposition. Throughout we keep as a leading thread the actual practical value of such techniques in terms of their efficiency to solve energy related problems.

[Claudia Sagastizábal](#) is on leave from a researcher position at INRIA, in France, and is currently adjunct as a long-term visitor to IMPA, in Rio de Janeiro. After finishing her undergraduate math studies in Argentina, Claudia moved to Paris, where she got her PhD in 1993 and her habilitation degree in 1998, both at the University Paris I Panthéon-Sorbonne. She has taught optimization in Argentina, France, and Brazil and is co-author of the book “Numerical Optimization: Theoretical and Practical Aspects” published by Springer. Claudia has also served in various program committees of international conferences and was elected Council Member-at-large in the Mathematical Optimization Society for the period 2009–2012. In parallel with her academic activities, Claudia has held consulting appointments for companies such as Electricité de France, Gaz de France-Suez, Renault-France, Robert Bosch, Petrobras, and Eletrobras. Her research interests lie in the areas of nonsmooth optimization as well as convex and variational analysis, always driven by real-life applications, with emphasis on the energy sector.

Semi-plenary lecture

Wed.17:00.H0105

Robert Weismantel

Mixed integer convex optimization

Chair Gérard Cornuéjols

This talk deals with algorithms and complexity results about the minimization of convex functions over integer points in convex regions. We begin with a survey about the current state of art. Then we discuss results about the speed of convergence of a black box algorithm that iteratively solves special quadratic integer subproblems with a constant approximation factor. Despite the generality of the underlying problem we prove that we can detect efficiently w.r.t. our assumptions regarding the encoding of the problem a feasible solution whose objective function value is close to the optimal value. We also show that this proximity result is best possible up to a polynomial factor. Next we discuss a new “cone-shrinking algorithm” that allows us to prove that integer convex optimization with a constant number of variables is polynomial time solvable. Parts of our results are based on joint work with M. Baes, A. del Pia, Y. Nesterov, S. Onn. The other part is based on joint work with M. Baes, T. Oertel, C. Wagner.

[Robert Weismantel](#) was born in 1965 in München, Germany. After studying mathematics at the University of Augsburg, he moved with Martin Grötschel to the Konrad-Zuse-Zentrum für Informationstechnik in Berlin (ZIB) in 1991. From the TU Berlin he received his PhD degree in 1992 and his second PhD degree (Habilitation) in 1995. In the years 1991–1997 he was a researcher at ZIB. From 1998 to 2010 he was a Professor (C4) for Mathematical Optimization at the University of Magdeburg. In 2010, he was elected Full Professor at the Department of Mathematics at ETH Zurich. His main research interest is integer and mixed integer optimization: specifically he was working on primal integer programming, the theory of Hilbert bases, and cutting plane theory. More recently he is working on nonlinear integer optimization. His work has been distinguished with several prizes and honors: His PhD thesis was awarded a Carl Ramsauer Prize. He received the Gerhard Hess Research Prize of the German Science Foundation and IBM-Faculty Awards in 2007 and 2010. He is currently a Co-Editor of Mathematical Programming A.

Thursday

Plenary lecture

Thu.09:00.H0105

Richard G. Baraniuk

Compressive signal processing

Chair Luís Nunes Vicente

Sensing and imaging systems are under increasing pressure to accommodate ever larger and higher-dimensional data sets; ever faster capture, sampling, and processing rates; ever lower power consumption; communication over ever more difficult channels; and radically new sensing modalities. This talk will overview the foundations and recent progress on compressive signal processing, a new approach to data acquisition and processing in which analog signals are digitized and processed not via uniform sampling but via measurements using more general, even random, test functions. In stark contrast with conventional wisdom, the new theory asserts that one can combine “sub-Nyquist-rate sampling” with large-scale optimization for efficient and accurate signal acquisition when the signal has a sparse structure. The implications of compressive sensing are promising for many applications and enable the design of new kinds of communication systems, cameras, imagers, microscopes, and pattern recognition systems. Special emphasis will be placed on the pros and cons of the compressive sensing technique.

[Richard G. Baraniuk](#) is the Victor E. Cameron Professor of Electrical and Computer Engineering at Rice University. His research interests lie in new theory, algorithms, and hardware for sensing, signal processing, and machine learning. He is a Fellow of the IEEE and AAAS and has received national young investigator awards from the US NSF and ONR, the Rosenbaum Fellowship from the Isaac Newton Institute of Cambridge University, the ECE Young Alumni Achievement Award from the University of Illinois, and the Wavelet Pioneer and Compressive Sampling Pioneer Awards from SPIE. His work on the Rice single-pixel compressive camera has been widely reported in the popular press and was selected by MIT Technology Review as a TR10 Top 10 Emerging Technology for 2007. For his teaching and education projects, including Connexions (cnx.org), he has received the C. Holmes MacDonald National Outstanding Teaching Award from Eta Kappa Nu, Tech Museum of Innovation Laureate Award, the Internet Pioneer Award from the Berkman Center for Internet and Society at Harvard Law School, the World Technology Award for Education, the IEEE-SPS Education Award, and the WISE Education Award.

Semi-plenary lecture

Thu.17:00.H0104

Michael P. Friedlander

Data fitting and optimization with randomized sampling

Chair Luís Nunes Vicente

For many structured data-fitting applications, incremental gradient methods (both deterministic and randomized) offer inexpensive iterations by sampling only subsets of the data. They make great progress initially, but eventually stall. Full gradient methods, in contrast, often achieve steady convergence, but may be prohibitively expensive for large problems. Applications in machine learning and robust seismic inversion motivate us to develop an inexact gradient method and sampling scheme that exhibit the benefits of both incremental and full gradient methods.

[Michael P. Friedlander](#) is Associate Professor of Computer Science at the University of British Columbia. He received his PhD in Operations Research from Stanford University in 2002, and his BA in Physics from Cornell University in 1993. From 2002 to 2004 he was the Wilkinson Fellow in Scientific Computing at Argonne National Laboratory. He was a senior fellow at UCLA’s Institute for Pure and Applied Mathematics in 2010. He serves on the editorial boards of SIAM J. on Optimization, SIAM J. on Matrix Analysis and Applications, Mathematical Programming Computation, Optimization Methods and Software, and the Electronic Transactions on Numerical Analysis. His research is primarily in developing numerical methods for constrained optimization, their software implementation, and applications in signal processing and image reconstruction.

Friday

Semi-plenary lecture

Thu.17:00.H0105

Amin Saberi

Rounding by sampling and traveling salesman problems

Chair Friedrich Eisenbrand

I will talk about a new technique for rounding the solution of linear programming relaxations of combinatorial optimization problems. In particular, I will present new algorithms for symmetric and asymmetric traveling salesman problems, improving the best known approximation ratios for these problems.

[Amin Saberi](#) is an Associate Professor and 3COM faculty scholar in Stanford University. He received his B.Sc. from Sharif University of Technology and his PhD from Georgia Institute of Technology in Computer Science. His research interests include algorithms, approximation algorithms, and algorithmic aspects of games, markets, and networks. He is a Frederick Terman Fellow (2005–2010), an Alfred Sloan Fellow (2010–2012), and the recipient of National Science Foundation Career award as well as best paper awards in FOCS 2011 and SODA 2010.

Semi-plenary lecture

Fri.09:00.H0105

Nikhil Bansal

Semidefinite optimization in discrepancy theory

Chair Friedrich Eisenbrand

The concept of discrepancy is intimately related to several fundamental topics in mathematics and theoretical computer science, and deals with the following type of question. Given a collection of sets on some elements, color each element red or blue such that each set in the collection is colored as evenly as possible. Recently, there have been several new developments in discrepancy theory based on connections to semidefinite programming. This connection has been useful in several ways. It gives efficient polynomial time algorithms for several problems for which only non-constructive results were previously known. It also leads to several new structural results in discrepancy itself, such as tightness of the so-called determinant lower bound, improved bounds on the discrepancy of the union of set systems and so on. We will give a brief survey of these results, focussing on the main ideas and the techniques involved.

[Nikhil Bansal](#) is an Associate Professor in the Department of Mathematics and Computer Science at Eindhoven University of Technology. He obtained his PhD from Carnegie Mellon University in 2003, and worked at the IBM T.J. Watson Research Center until 2011, where he also managed the Algorithms group. His main research interests are the design and analysis of approximation and online algorithms. For his work, he has co-received best paper awards at FOCS 2011, ESA 2011 and ESA 2010, and also IBM Research best paper awards for 2007 and 2010.

Semi-plenary lecture

Fri.09:00.H0104

Xiaojun Chen

Nonsmooth, nonconvex regularized optimization for sparse approximations

Chair Ya-xiang Yuan

Minimization problems with nonsmooth, nonconvex, perhaps even non-Lipschitz regularization terms have wide applications in image restoration, signal reconstruction and variable selection, but they seem to lack optimization theory. On L_p non-Lipschitz regularized minimization, we show that finding a global optimal solution is strongly NP-hard. On the other hand, we present lower bounds of nonzero entries in every local optimal solution without assumptions on the data matrix. Such lower bounds can be used to classify zero and nonzero entries in local optimal solutions and select regularization parameters for desirable sparsity of solutions. Moreover, we show smoothing methods are efficient for solving such regularized minimization problems. In particular, we introduce a smoothing SQP method which can find an affine scaled epsilon-stationary point from any starting point with complexity $O(\epsilon^{-2})$, and a smoothing trust region Newton method which can find a point satisfying the affine scaled second order necessary condition from any starting point. Examples with six widely used nonsmooth nonconvex regularization terms are presented to illustrate the theory and algorithms. Joint work with W. Bian, D. Ge, L. Niu, Z. Wang, Y. Ye, Y. Yuan.

Xiaojun Chen received her PhD degree in Computational Mathematics from Xi'an Jiaotong University, China in 1987 and PhD degree in Applied Mathematics from Okayama University of Science, Japan in 1991. She was a postdoctoral fellow at the University of Delaware, an Australia Research Fellow in the University of New South Wales and a Professor in Hirosaki University, Japan. She joined the Hong Kong Polytechnic University as a Professor in 2007. Her current research interests include nonsmooth nonconvex optimization, stochastic equilibrium problems and numerical approximation methods on the sphere with important applications in engineering and economics. She has published over 80 papers in major international journals in operations research and computational mathematics. Prof. Chen has won many grants as a principal investigator from several government funding agencies and organized several important international conferences. She serves in the editorial boards of five mathematical journals including SIAM Journal on Numerical Analysis.

Plenary lecture

Fri.17:00.H0105

Jorge Nocedal

Second-order methods for stochastic, semi-smooth and nonlinear programming

Chair Philippe Toint

First-order methods have been advocated for solving optimization problems of large scale. Although they are sometimes the most appropriate techniques, we argue that in many applications it is advantageous to employ second-order information as an integral part of the iteration. This is particularly so when parallel computing environments are available. In this talk, we take a broad view of second-order methods, and center our discussion around three applications: convex L1 regularized optimization, inverse covariance estimation, and nonlinear programming. We note that many efficient methods for these problems can be derived using a semi-smooth Newton framework, which allows us to compare their manifold identification and subspace minimization properties. We propose an algorithm employing a novel active-set mechanism that is of interest in machine learning, PDE-constrained optimization, and other applications. We also discuss dynamic sampling techniques, illustrate their practical performance, and provide work complexity bounds. The talk concludes with some observations about the influence that parallel computing has on large scale optimization calculations.

Jorge Nocedal is a professor in the Industrial Engineering Department at Northwestern University. He holds a B.S. degree in physics from the National University of Mexico and a PhD in applied mathematics from Rice University. Prior to moving to Northwestern, he taught at the Courant Institute of Mathematical Sciences. He is a SIAM Fellow and an ISI Highly Cited Researcher (mathematics category). In 1998 he was appointed Bette and Neison Harris Professor at Northwestern. Jorge was an invited speaker at the 1998 International Congress of Mathematicians in Berlin. His research focuses on the theory, algorithms and applications of nonlinear programming, and he has developed widely used software, including L-BFGS and Knitro. He is currently Editor-in-Chief of the SIAM Journal on Optimization.

HISTORICAL LECTURES: Monday

Historical lecture

Mon.17:00.H1012

Horst Zuse

The origins of the computer

Chair Martin Grötschel

Many outstanding scientists and managers were necessary to get the computer to the point of development that we know today. Konrad Zuse (1910–1995) is almost unanimously accepted as the inventor of the first working, freely programmable machine using Boolean logic and binary floating point numbers. This Machine – called Z3 – was finished by Konrad Zuse in May 1941 in his small workshop in Berlin-Kreuzberg. In this presentation the achievements of Charles Babbage (1823), the development of the secret COLOSSUS-Project (UK, 1943), Howard Aiken's Mark I (USA), and the ENIAC (USA) are outlined. Konrad Zuse's contributions to computer development are presented, of course, as well, with many surprising pictures and videos. It is not well known that Konrad Zuse founded, in 1949, a computer company that produced 251 computers of a value of 51 Million Euros. It was the first company which produced computers in a commercial way.

Horst Zuse, the oldest of Konrad Zuse's five children, was born on November 17, 1945 in Hindelang (Bavaria, Germany). He received his PhD degree in computer science from Technische Universität Berlin (TUB) in 1985. From 1975–2010 he was a senior research scientist at TUB. His research interests are information retrieval systems, software engineering, software metrics, computer history and computer architectures. In 1991 he published the book *Software Complexity – Measures and Methods* (De Gruyter Publisher). In 1998 the book *A Framework for Software Measurement* (De Gruyter Publisher) followed. In 1998 he received the habilitation (Privatdozent) in the area of Praktische Informatik (Practical Computer Science), and since 2006 he has been a Professor at the University of Applied Sciences in Senftenberg.

Tuesday

Historical lecture

Tue.17:00.H1012

Eberhard Knobloch

Gottfried Wilhelm Leibniz – Universal genius and outstanding mathematician

Chair Günter M. Ziegler

The universal genius Gottfried Wilhelm Leibniz (1646–1716) contributed to nearly all scientific disciplines and left the incredibly huge amount of about 200,000 sheets of paper that are kept in the Leibniz Library of Hannover. About 4,000 of them regarding natural sciences, medicine, technology have been digitized and are freely available in the internet: <http://ritter.bbaw.de>. Less than half of them have been published up to now. Hence we know for example – for the time being – only about one fourth of his mathematical production. The lecture will give a short survey of his biography and mainly deal with the following six aspects: 1. Leibniz as an organizer of scientific work: His presidency of the Berlin Academy of Sciences; 2. His rigorous foundation of infinitesimal geometry; 3. Leibniz as the inventor of the differential and integral calculus; 4. His conception of and his contributions to a general combinatorial art (symmetric functions, number theory, insurance calculus); 5. His proposals for engineering improvements in mining; 6. Leibniz's invention of the first real four-function calculating machine.

Eberhard Knobloch, born in 1943 in Görlitz, Germany, studied mathematics, classical philology, and history of science and technology at Freie Universität Berlin and Technische Universität Berlin. In 1972 he did a PhD in history of science and technology, in 1976 he passed the habilitation for university professors at Technische Universität Berlin. Since 2002 he is professor of history of science and technology at this university and Academy professor at the Berlin-Brandenburg Academy of Sciences and Humanities (BBAW). He is a member of several national and international academies of sciences, president of the International Academy of the History of Science, past president of the European Society for the History of Science, Honorary professor of the Chinese Academy of Sciences. He published or edited more than 300 papers or books on the history of science and technology, he is a member of the editorial boards of sixteen international journals. His main scientific interests concern the history and philosophy of mathematical sciences and Renaissance technology. He is project leader of the A. v. Humboldt research group and the two Leibniz research groups at BBAW.

Wednesday

Historical lecture

Wed.17:00.H1012

Günter M. Ziegler

Leonhard Euler: Three strikes of a genius

Chair George Nemhauser

We will explore three of Euler's genius contributions: The seven bridges of Königsberg: How a problem of "Recreational Mathematics" led to the creation of Graph Theory.

The Basel problem: A healthy dose of serious numerical computing on the way to a $\zeta(2)$.

The polyhedron formula: Tracing the polyhedron formula from Stockholm to the Berne mountains.

Günter M. Ziegler, born in München, Germany, in 1963, got a PhD at MIT in 1987, became a Professor of Mathematics at TU Berlin 1995, and moved to FU Berlin in 2011 as a MATHEON Professor. He became the founding chair of the Berlin Mathematical School in 2006. His interests connect discrete and computational geometry (especially polytopes), algebraic and topological methods in combinatorics, discrete mathematics and the theory of linear and integer programming. He is the author of *Lectures on Polytopes* (Springer 1995) and of *Proofs from THE BOOK* (with Martin Aigner, Springer-Verlag 1998), which has by now appeared in 14 languages. His latest book is *Darf ich Zahlen? Geschichten aus der Mathematik (Do I count? Stories from Mathematics; English translation to appear)*. Günter Ziegler's honors include a Leibniz Prize (2001) of the German Research Foundation DFG, the Chauvenet Prize (2004) of the Mathematical Association of America, and the 2008 Communicator Award of DFG and Stifterverband. He is a member of the executive board of the Berlin-Brandenburg Academy of Sciences, and a member of the German National Academy of Sciences Leopoldina. From 2006–2008 he was the President of the German Mathematical Society DMV. In 2008 he initiated and co-organized the German National Science Year "Jahr der Mathematik" and now directs the DMV Mathematics Media Office and the DMV Network Office Schools–Universities.

IPCO 2013

The 16th Conference on Integer Programming and Combinatorial Optimization (IPCO XVI) will take place at the Universidad Técnica Federico Santa María (UTFSM) in Valparaíso, Chile, from March 18 to March 20, 2013. Please note the unusual date.

The main campus of the UTFSM is located in the border between the cities of Valparaíso and Viña del Mar. Valparaíso, located 112 km northwest of Santiago is recognized as one of the most attractive places in Latin America, while Viña del Mar, the "Garden City", is the tourism capital of Chile.

The IPCO conference is supported by the Mathematical Optimization Society (formerly known as the Mathematical Programming Society). It is held every year, except for those years in which the International Symposium on Mathematical Programming (ISMP) takes place. This conference is a forum for researchers and practitioners working on integer programming and combinatorial optimization. Its aim is to present recent developments in the theory, computation, and applications in these areas.

The program committee is chaired by Michel Goemans, and the organizing committee is chaired by José Correa.

Submission deadline: October 24, 2012

For further details, please visit <http://ipco2013.dim.uchile.cl>

Thursday

Historical lecture

Thu.17:00.H1012

Jürgen Sprekels

Karl Weierstrass and optimization

Chair Richard Cottle

The work of Karl Weierstrass, the outstanding Berlin mathematician who was one of leading mathematical researchers of the second half of the nineteenth century, had a deep impact on the theory of optimization and on variational calculus. In this talk, we review some aspects of his contributions to the field.

Jürgen Sprekels, born 1948 in Hamburg, Germany, studied mathematics at the University of Hamburg, where he received his PhD in 1975 and his habilitation in 1977. After professorships in Augsburg (1981–88) and Essen (1988–94), he became Full Professor for Applied Analysis at the Humboldt-Universität zu Berlin in 1994. Since 1994 he has been the director of the Weierstrass Institute for Applied Analysis and Stochastics (WIAS) in Berlin, the non-university mathematical research institute that hosts the Secretariat of the International Mathematical Union (IMU) and the German Mathematical Society (DMV). He was also one of the founders of the mathematical research center MATHEON in Berlin. His research focuses on the analysis and optimal control of nonlinear systems of PDEs arising in applications, with an emphasis on hysteresis phenomena, phase transitions, and free boundary problems. He conducted several industrial cooperation projects, in particular, in the growth of semiconductor bulk single crystals. He (co-)authored two research monographs and more than 150 papers in refereed journals and conference proceedings.

Historical lecture

Thu.17:30.H1012

Martin Grötschel

Hermann Minkowski and convexity

Chair Richard Cottle

Convexity of a set or function is a property that plays an important role in optimization. In this lecture a brief survey of the history of the notion of convexity and, in particular, the role Hermann Minkowski played in it, will be given.

Martin Grötschel, born in Schwelm, Germany in 1948, studied mathematics and economics at Ruhr-Universität Bochum from 1969–1973. He received his PhD (1977) and his habilitation (1981) from Bonn University. He was Full Professor of Applied Mathematics at Augsburg University (1982–1991). Since 1991 he has been Professor at the Institute of Mathematics of Technische Universität Berlin and Vice President of the Zuse Institute Berlin (ZIB). From 2002 to 2008 he served as chair of the DFG Research Center MATHEON. Martin Grötschel was President of the German Mathematical Society DMV 1993–1994, and he has been serving the International Mathematical Union as Secretary since 2007. He is a member of four academies (BBAW, Leopoldina, acatech, NAE) and since 2001 in the executive board of BBAW. In 2011 he became chairman of the executive board of the Einstein Foundation Berlin. His scientific honors include the Leibniz, the Dantzig and the Fulkerson Prize and four honorary degrees. His main areas of scientific interest are discrete mathematics, optimization and operations research with a particular emphasis on the design of theoretically and practically efficient algorithms for hard combinatorial optimization problems occurring in practice.

LIST OF CLUSTERS AND CLUSTER CHAIRS

- **Approximation and online algorithms**
Organizer: Leen Stougie, David P. Williamson
- **Combinatorial optimization**
Organizer: Jochen Könnemann, Jens Vygen
- **Complementarity and variational inequalities**
Organizer: Michael C. Ferris, Michael Ulbrich
- **Conic programming**
Organizer: Raphael Hauser, Toh Kim Chuan
- **Constraint programming**
Organizer: Michela Milano, Willem-Jan van Hoeve
- **Derivative-free and simulation-based optimization**
Organizer: Luís Nunes Vicente, Stefan Wild
- **Finance and economics**
Organizer: Thomas F. Coleman, Karl Schmedders
- **Game theory**
Organizer: Asu Ozdaglar, Guido Schäfer
- **Global optimization**
Organizer: Christodoulos A. Floudas, Nikolaos V. Sahinidis
- **Implementations and software**
Organizer: Tobias Achterberg, Andreas Wächter
- **Integer and mixed-integer programming**
Organizer: Andrea Lodi, Robert Weismantel
- **Life sciences and healthcare**
Organizer: Gunnar W. Klau, Ariela Sofer
- **Logistics, traffic, and transportation**
Organizer: Marco E. Lübbecke, Georgia Perakis
- **Mixed-integer nonlinear programming**
Organizer: Sven Leyffer, François Margot
- **Multi-objective optimization**
Organizer: Jörg Fliege, Johannes Jahn
- **Nonlinear programming**
Organizer: Philip E. Gill, Stephen J. Wright
- **Nonsmooth optimization**
Organizer: Amir Beck, Jérôme Bolte
- **Optimization in energy systems**
Organizer: Alexander Martin, Claudia Sagastizábal
- **PDE-constrained optimization and multi-level/multi-grid methods**
Organizer: Matthias Heinkenschloss, Michael Hintermüller
- **Robust optimization**
Organizer: Aharon Ben-Tal, Dimitris Bertsimas
- **Sparse optimization and compressed sensing**
Organizer: Ben Recht, Michael Saunders, Stephen J. Wright
- **Stochastic optimization**
Organizer: Shabbir Ahmed, David Morton
- **Telecommunications and networks**
Organizer: Andreas Bley, Mauricio G. C. Resende
- **Variational analysis**
Organizer: René Henrion, Boris Mordukhovich

ICCOPT 2013

ICCOPT 2013, The Fourth International Conference on Continuous Optimization, will take place in Lisbon, Portugal, from July 27 to August 1, 2013. ICCOPT is a recognized forum of discussion and exchange of ideas for researchers and practitioners in continuous optimization, and one of the flagship conferences of the Mathematical Optimization Society.

ICCOPT 2013 is organized by the Department of Mathematics of FCT, Universidade Nova de Lisboa, in its Campus de Caparica, located near a long beach, 15 minutes away by car (and 30 by public transportation) from the center of Lisbon, on the opposite side of the river Tagus.

ICCOPT 2013 includes a Conference and a Summer School. The Conference (July 29 – August 1) will count with the following Plenary Speakers:

- Paul I. Barton (MIT, Massachusetts Inst. Tech.)
- Michael C. Ferris (Univ. Wisconsin)
- Yurii Nesterov (Univ. Catholique de Louvain)
- Yinyu Ye (Stanford Univ.)

and the following Semi-plenary Speakers:

- Amir Beck (Technion, Israel Inst. Tech.)
- Regina Burachik (Univ. South Australia)
- Sam Burer (Univ. Iowa)
- Coralía Cartis (Univ. Edinburgh)
- Michel De Lara (Univ. Paris-Est)
- Victor DeMiguel (London Business School)
- Michael Hintermüller (Humboldt-Univ. Berlin)
- Ya-xiang Yuan (Chinese Academy of Sciences)

The Summer School (July 27–28) is directed to graduate students and young researchers in the field of continuous optimization, and includes two courses:

Summer Course on PDE-Constrained Optimization (July 27, 2013), by

Michael Ulbrich (Tech. Univ. Munich) Christian Meyer (Tech. Univ. Dortmund)

Summer Course on Sparse Optimization and Applications to Information Processing (July 28, 2013), by

Mário A. T. Figueiredo (Technical Univ. Lisbon and IT) Stephen J. Wright (Univ. Wisconsin)

There will be a paper competition for young researchers in Continuous Optimization (information available from the website below).

The three previous versions of ICCOPT were organized respectively in 2004 at Rensselaer Polytechnic Institute (Troy, NY, USA), in 2007 at McMaster University (Hamilton, Ontario, Canada), and in 2010 at University of Chile (FCFM, Santiago, Chile).

The meeting is chaired by Luis Nunes Vicente (Organizing Committee) and Katya Scheinberg (Program Committee) and locally coordinated by Paula Amaral (Local Organizing Committee).

The website is <http://eventos.fct.unl.pt/iccopt2013>

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EXHIBITORS

The exhibit area is located in the 'Lichthof' of the Main Building. The exhibition is open Monday, August 20, to Friday, August 24, 9:00–17:00.

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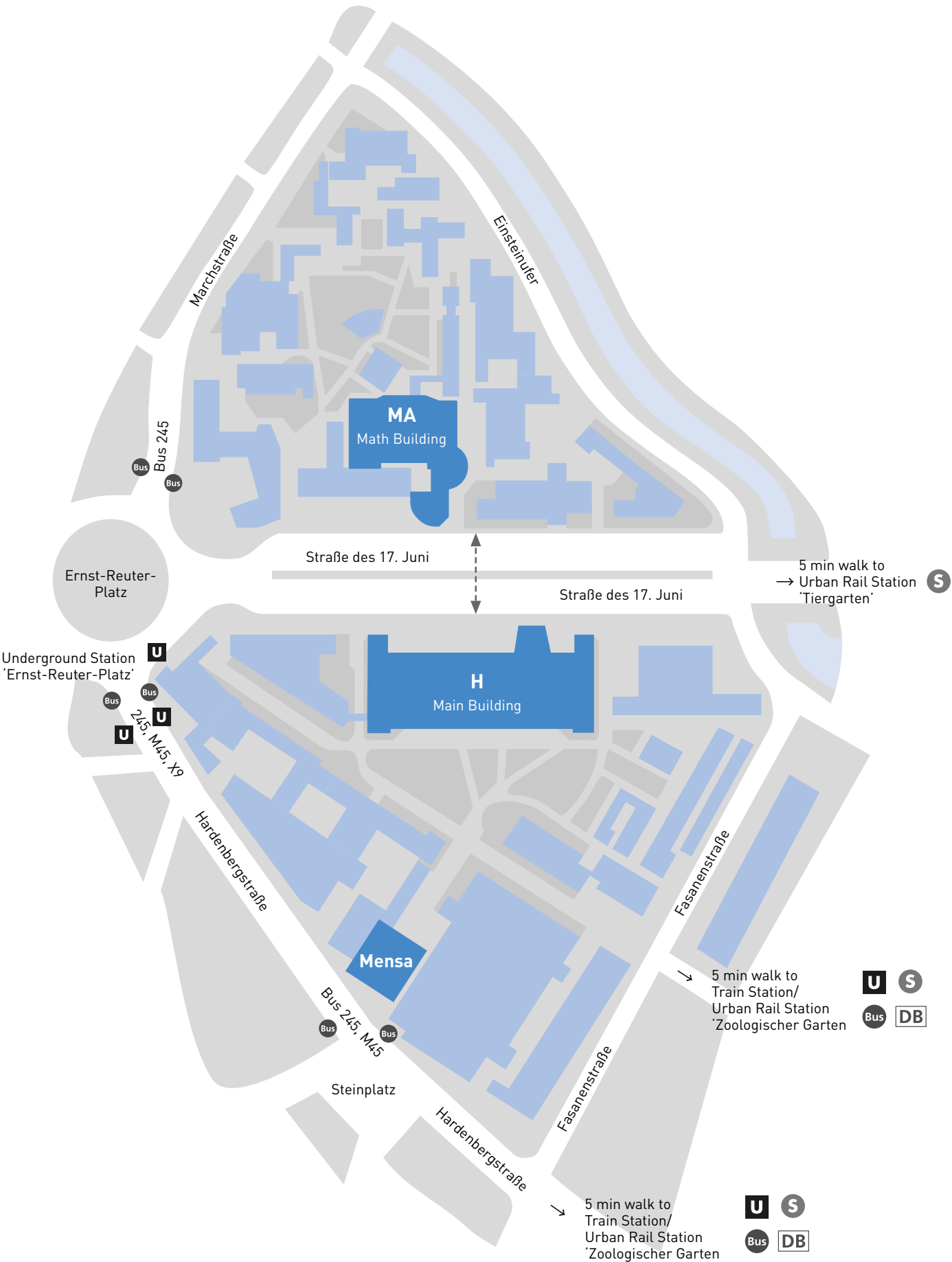


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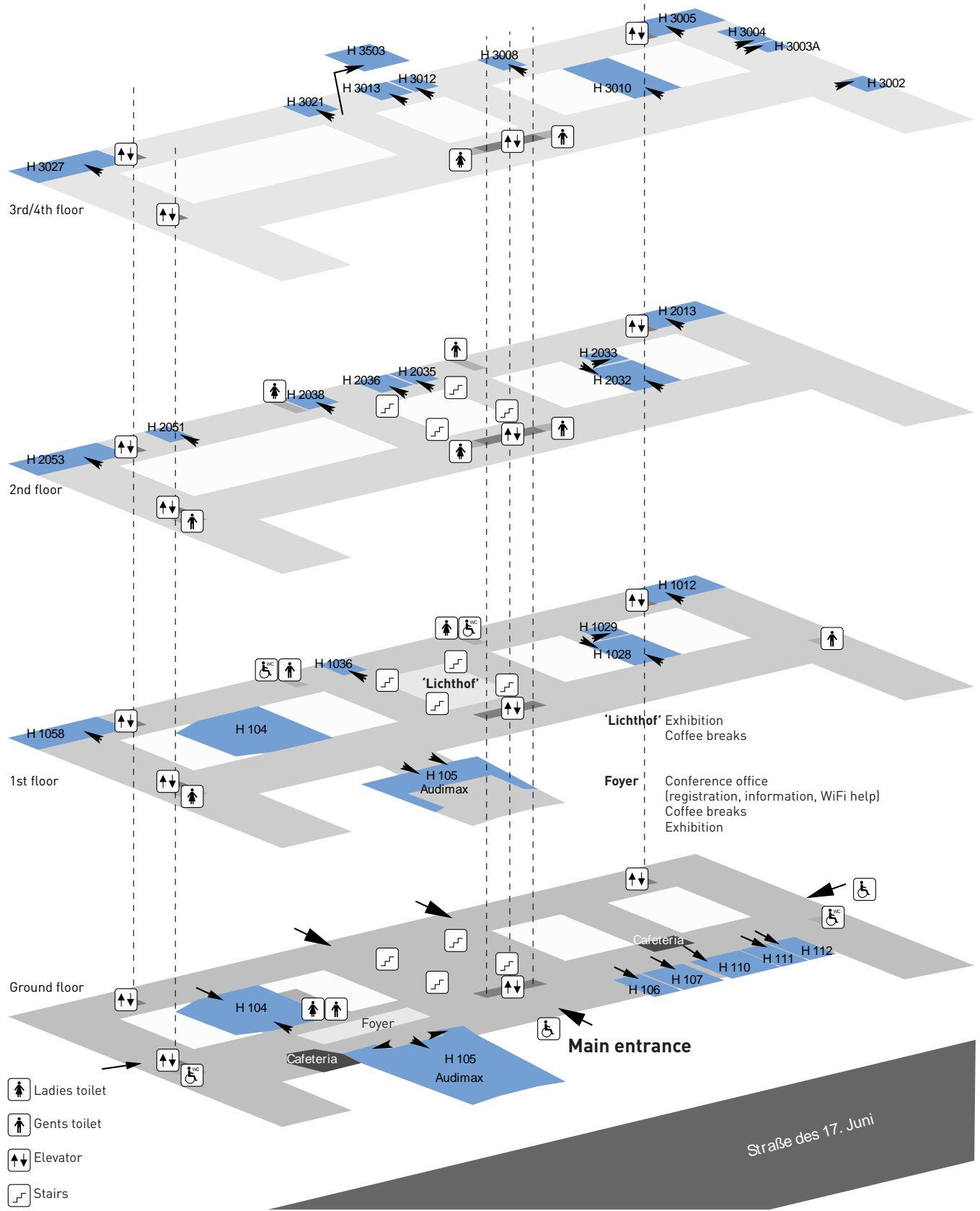
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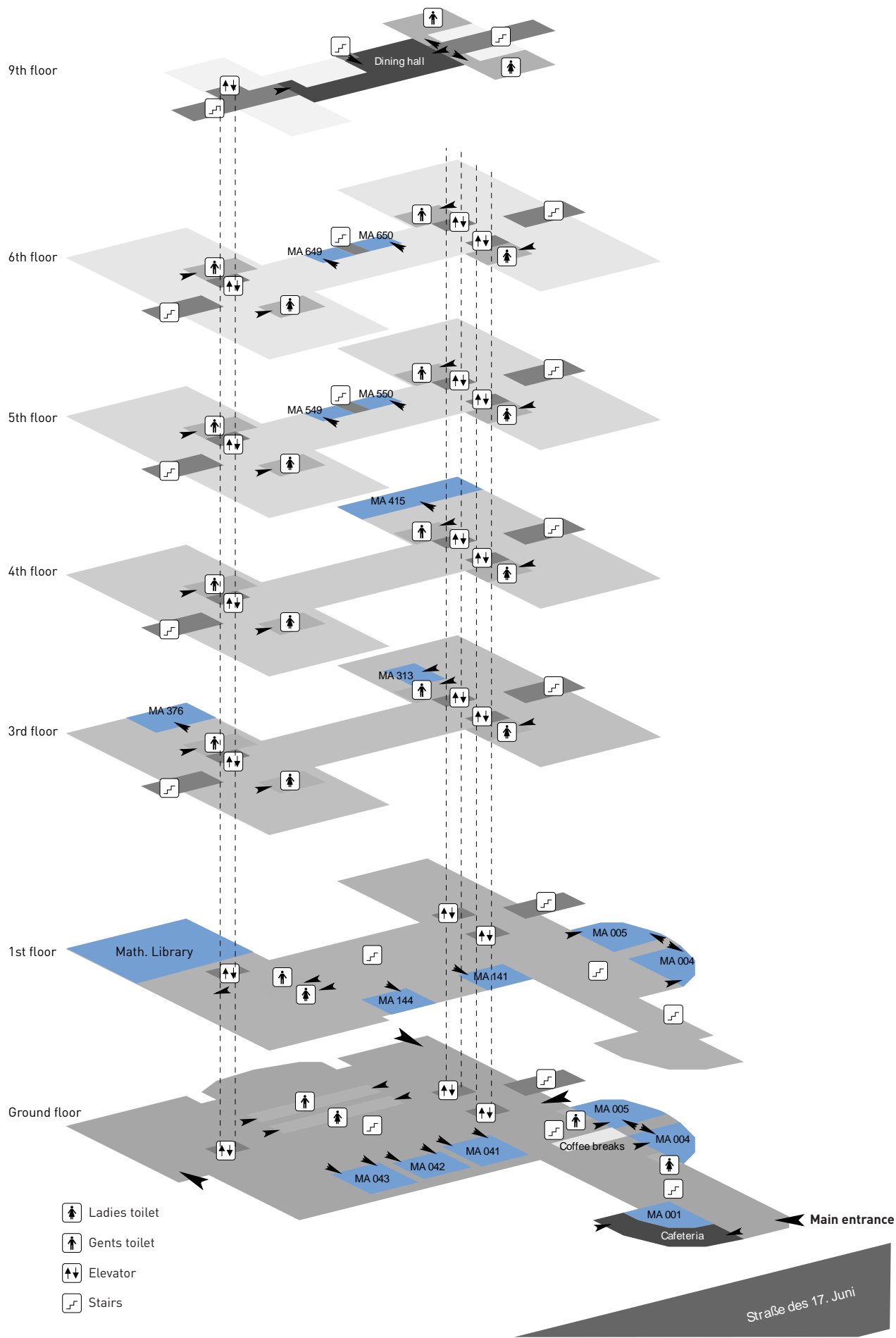






FLOOR PLANS



Main Building

Straße des 17. Juni



-  Ladies toilet
-  Gents toilet
-  Elevator
-  Stairs

Math Building

Daily events and sessions

	When?	What?	Where?
Friday, August 17	14:00–23:59	Airport Registration Service	Airports Tegel and Schönefeld
Saturday, August 18	00:00–23:59	Airport Registration Service	Airports Tegel and Schönefeld
Sunday, August 19	00:00–16:00	Airport Registration Service	Airports Tegel and Schönefeld
	15:00–18:00	Registration	Konzerthaus Berlin
	18:00–22:00	Opening Ceremony & Reception	Konzerthaus Berlin
Monday, August 20	07:00–18:30	Registration	Main Building of TU Berlin
	09:00–17:00	Exhibits	'Lichthof,' Main Building
	09:00–09:50	Plenary Lecture: Rakesh Vohra	H0105, Main Building
	10:00–10:30	Coffee Break	Main Building and Math Building
	10:30–12:00	Technical Sessions (Mon.1)	Main Building and Math Building
	10:30–12:00	Tucker Prize Session	MA041, Math Building
	12:00–13:15	Lunch Break (on your own)	see Restaurant Guide
	13:15–14:45	Technical Sessions (Mon.2)	Main Building and Math Building
	14:45–15:15	Coffee Break	Main Building and Math Building
	15:15–16:45	Technical Sessions (Mon.3)	Main Building and Math Building
	17:00–17:50	Semi-Plenary Lecture: Katya Scheinberg	H0104, Main Building
	17:00–17:50	Semi-Plenary Lecture: Dimitris Bertsimas	H0105, Main Building
	17:00–17:50	Historical Lecture: Horst Zuse	H1012, Main Building
	18:00–20:00	Welcome Reception	'Lichthof,' Main Building
19:00–	MOS Council Meeting	H1035, Main Building	
Tuesday, August 21	07:30–18:30	Registration	Main Building of TU Berlin
	09:00–17:00	Exhibits	'Lichthof,' Main Building
	09:00–09:50	Plenary Lecture: Robin Thomas	H0105, Main Building
	10:00–10:30	Coffee Break	Main Building and Math Building
	10:30–12:00	Technical Sessions (Tue.1)	Main Building and Math Building
	12:00–13:15	Lunch Break (on your own)	see Restaurant Guide
	13:15–14:45	Technical Sessions (Tue.2)	Main Building and Math Building
	14:45–15:15	Coffee Break	Main Building and Math Building
	15:15–16:45	Technical Sessions (Tue.3)	Main Building and Math Building
	17:00–17:50	Tseng Memorial Lecture	H0105, Main Building
	17:00–17:50	Semi-Plenary Lecture: Teemu Pennanen	H0104, Main Building
	17:00–17:50	Semi-Plenary Lecture: Rekha Thomas	H1058, Main Building
	17:00–17:50	Historical Lecture: Eberhard Knobloch	H1012, Main Building
	18:15–	MOS Business Meeting	H0105, Main Building

	When?	What?	Where?
Wednesday, August 22	07:30–18:30	Registration	Main Building of TU Berlin
	09:00–17:00	Exhibits	'Lichthof,' Main Building
	09:00–09:50	Plenary Lecture: Christof Schütte	H0105, Main Building
	10:00–10:30	Coffee Break	Main Building and Math Building
	10:30–12:00	Technical Sessions (Wed.1)	Main Building and Math Building
	12:00–13:15	Lunch Break (on your own)	see Restaurant Guide
	12:00–13:15	MP Journal Board Meeting	H1035, Main Building
	13:15–14:45	Technical Sessions (Wed.2)	Main Building and Math Building
	13:15–14:45	TomTom Session	H0104, Main Building
	14:45–15:15	Coffee Break	Main Building and Math Building
	15:15–16:45	Technical Sessions (Wed.3)	Main Building and Math Building
	17:00–17:50	Semi-Plenary Lecture: Claudia Sagastizábal	H0104, Main Building
	17:00–17:50	Semi-Plenary Lecture: Robert Weismantel	H0105, Main Building
	17:00–17:50	Historical Lecture: Günter M. Ziegler	H1012, Main Building
	19:00–	Conference Dinner	Haus der Kulturen der Welt

Thursday, August 23	07:30–18:30	Registration	Main Building of TU Berlin
	09:00–17:00	Exhibits	'Lichthof,' Main Building
	09:00–09:50	Plenary Lecture: Richard Baraniuk	H0105, Main Building
	10:00–10:30	Coffee Break	Main Building and Math Building
	10:30–12:00	Technical Sessions (Thu.1)	Main Building and Math Building
	12:00–13:15	Lunch Break (on your own)	see Restaurant Guide
	13:15–14:45	Technical Sessions (Thu.2)	Main Building and Math Building
	14:45–15:15	Coffee Break	Main Building and Math Building
	15:15–16:45	Technical Sessions (Thu.3)	Main Building and Math Building
	15:15–16:45	Klaus Tschira Session (in German)	MA041, Math Building
	17:00–17:50	Semi-Plenary Lecture: Michael P. Friedlander	H0104, Main Building
	17:00–17:50	Semi-Plenary Lecture: Amin Saberi	H0105, Main Building
	17:00–17:25	Historical Lecture: Jürgen Sprekels	H1012, Main Building
	17:30–17:55	Historical Lecture: Martin Grötschel	H1012, Main Building

Friday, August 24	07:30–18:30	Registration	Main Building of TU Berlin
	09:00–17:00	Exhibits	'Lichthof,' Main Building
	09:00–09:50	Semi-Plenary Lecture: Xiaojun Chen	H0104, Main Building
	09:00–09:50	Semi-Plenary Lecture: Nikhil Bansal	H0105, Main Building
	10:00–10:30	Coffee Break	Main Building and Math Building
	10:30–12:00	Technical Sessions (Fri.1)	Main Building and Math Building
	12:00–13:15	Lunch Break (on your own)	see Restaurant Guide
	13:15–14:45	Technical Sessions (Fri.2)	Main Building and Math Building
	14:45–15:15	Coffee Break	Main Building and Math Building
	15:15–16:45	Technical Sessions (Fri.3)	Main Building and Math Building
	17:00–17:50	Plenary Lecture: Jorge Nocedal	H0105, Main Building
	18:00–	Farewell Gathering	'Lichthof,' Main Building

<p>Special session: Tucker session (Organizer: Daniel Ralph) [p. 74] Tucker awards ceremony: Presentation by Tucker Prize Finalist</p>	<p>MA 041</p>
<p>Approximation and online algorithms: Approximation in routing and others (Organizers: Sylvia Boyd and David Shmoys) [p. 74] Hyung-Chan An: Improving Christofides' algorithm for the $s-t$ path TSP</p>	<p>H 3010</p>
<p>Combinatorial optimization: Combinatorial optimization in chip design I (Organizer: Stephan Held) [p. 74] Igor Markov: A primal-dual Lagrange optimization for VLSI global placement</p>	<p>H 3004</p>
<p>Combinatorial optimization: Triangulations (Organizer: Lionel Pournin) [p. 74] Lionel Pournin: The flip-graph of the 4-dimensional cube is connected</p>	<p>H 3005</p>
<p>Combinatorial optimization: Rational convex programs and combinatorial algorithms for solving them (Organizer: Vijay Vazirani) [p. 75] Vijay Vazirani: Rational convex programs</p>	<p>H 3008</p>
<p>Combinatorial optimization: Matching [p. 75] Sigrid Knust: Scheduling sports tournaments on a single court based on special 2-factorizations</p>	<p>H 3012</p>
<p>Combinatorial optimization: Combinatorial optimization in railways I (Organizer: Ralf Borndörfer) [p. 75] Jun Imaizumi: A column generation approach for crew rostering problem in a freight railway company in Japan</p>	<p>H 3013</p>
<p>Combinatorial optimization: Scheduling algorithms I (Organizer: Nikhil Bansal) [p. 76] Kirk Pruhs: Online primal-dual for non-linear optimization with applications to speed scaling</p>	<p>H 3021</p>
<p>Completeness and variational inequalities: Optimization and equilibrium models in energy systems (Organizer: Jong-Shi Pang) [p. 76] Steven Gabriel: A new method for MPECs with a natural gas application</p>	<p>MA 313</p>
<p>Conic programming: Geometry and duality in convex programming (Organizer: Gabor Pataki) [p. 76] Hayato Waki: Computation of facial reduction algorithm</p>	<p>H 2036</p>
<p>Conic programming: Applications of semidefinite optimization (Organizer: Miguel Anjos) [p. 77] Henry Wolkowicz: Taking advantage of degeneracy in cone optimization with applications to sensor network localization and molecular conformation</p>	<p>H 2038</p>
<p>Constraint programming: Constraint-based scheduling (Organizer: Petr Vliím) [p. 77] Andre Cire: MDD propagation for disjunctive scheduling</p>	<p>H 3003A</p>
<p>Finance and economics: Applications of stochastic programming to finance and insurance (Organizer: Giorgio Consigli) [p. 77] Andrea Consigli: Convex lower bounding to generate multi-asset, arbitrage-free, scenario trees</p>	<p>H 3027</p>
<p>Game theory: Games in networks (Organizer: Konstantinos Bimpikis) [p. 78] Yann Bramoulle: Network games under strategic complementarities</p>	<p>MA 043</p>

<p>Global optimization: Optimization models and methods for computer vision (Organizers: Jiming Peng and Vikas Singh) [p. 78] Vladimir Kolmogorov: Message passing algorithms for MAP-MRF inference</p>	<p>Maxwell Collins: Random walks based multi-image segmentation: Quasiconvexity results and GPU-based solutions</p>	<p>H 2053</p>
<p>Implementations and software: Testing environments for machine learning and compressed sensing (Organizer: Katya Scheinberg) [p. 79] Michael Friedlander: Spot: A linear-operator toolbox for Matlab Katya Scheinberg: Studying effects of various step selection strategies in first order approaches to compressed sensing and other composite optimization problems</p>	<p>Dirk Lorenz: Constructing test instances for basis pursuit denoising</p>	<p>H 1058</p>
<p>Integer and mixed-integer programming: Column generation and decomposition [p. 79] Richard Lusby: A column generation approach for solving the patient admission scheduling problem</p>	<p></p>	<p>H 2013</p>
<p>Integer and mixed-integer programming: Integer programming algorithms I [p. 79] Chuangyin Dang: A fixed-point iterative approach to integer programming and distributed computation Thomas Rehn: Exploiting symmetry in integer convex optimization using core points</p>	<p>Timm Oertel: Convex integer minimization in fixed dimension</p>	<p>H 2032</p>
<p>Integer and mixed-integer programming: Advances in integer programming (Organizer: Shmuel Onn) [p. 79] Antoine Deza: Combinatorial, computational, and geometric approaches to the colourful simplicial depth</p>	<p>Matthias Köppe: A discretization-free FPTAS for polynomial optimization over the mixed-integer points in a class of polytopes of varying dimension</p>	<p>MA 004</p>
<p>Integer and mixed-integer programming: Recent progress in MIP (Organizer: Oktay Günlük) [p. 80] Marco Molinaro: Strength of cross cuts</p>	<p>Egon Balas: Cut-generating points on the boundary of a lattice-free convex set</p>	<p>MA 042</p>
<p>Life sciences and healthcare: Computational genomics (Organizer: Alexander Schönhuth) [p. 80] Hugues Richard: Fiona: Automatic correction of sequencing errors in genome sequencing experiments</p>	<p>Iman Hajirasouliha: Next-generation sequence characterization of complex genome structural variation.</p>	<p>H 2033</p>
<p>Logistics, traffic, and transportation: Facility location and p-median problems [p. 80] Sergio Garcia Quiles: On the p-median problem with uncertainty in the cost matrix</p>	<p>Haldun Sural: The dynamic p-median problem with relocation</p>	<p>H 0106</p>
<p>Logistics, traffic, and transportation: Supply chain optimization (Organizer: Edwin Romeijn) [p. 81] Joseph Geunes: Multi-period price promotions in a single-supplier, multi-retailer supply chain under asymmetric demand information</p>	<p>Zohar Strinka: Approximation algorithms for risk-averse selective newsvendor problems</p>	<p>H 0111</p>
<p>Mixed-integer nonlinear programming: Global mixed-integer nonlinear optimization I (Organizer: Ignacio Grossmann) [p. 81] Ignacio Grossmann: Using convex nonlinear relaxations in the global optimization of nonconvex generalized disjunctive programs</p>	<p>Tapio Westerlund: A reformulation framework for global optimization</p>	<p>MA 005</p>
<p>Multi-objective optimization: Linear and integer multiobjective optimization [p. 82] Markku Kallio: Reference point method for multi-criteria optimization with integer variables</p>	<p>Mohammad Ali Yaghoobi: Using ball center of a polytope to solve a multiobjective linear programming problem</p>	<p>H 1029</p>
<p>Nonlinear programming: Methods for nonlinear optimization I [p. 82] Xin-Wei Liu: How does the linear independence assumption affect algorithms of nonlinear constrained optimization</p>	<p>Jean-Pierre Dussault: The behaviour of numerical algorithms without constraint qualifications</p>	<p>H 0107</p>
<p>Nonlinear programming: Nonlinear optimization I (Organizers: Frank E. Curtis and Daniel Robinson) [p. 82] Eckstein Jonathan: Alternating direction methods and relative error criteria for augmented Lagrangians</p>	<p>Stefan Sointsev: Dynamic batch methods for L1 regularized problems and constrained optimization</p>	<p>H 0110</p>
<p>Nonlinear programming: Algorithms for optimal control I [p. 83] Dennis Janka: Separable formulations of optimum experimental design problems</p>	<p>Carsten Gräser: Truncated nonsmooth newton multigrad methods for nonsmooth minimization</p>	<p>H 0112</p>

<p>Nonsmooth optimization: Iterative methods for variational analysis [Organizer: Alain Pietrus] [p. 83] Celia Jean-Alexis: The second order generalized derivative and generalized equations</p>	<p>Elza Farkhi: The directed subdifferential and applications</p>	H 1012
<p>Optimization in energy systems: Optimization models to manage risk and uncertainty in power systems operations [Organizers: Raphael Chabbar and Luiz Barros] [p. 83] Alexandre Street: Energy and reserve scheduling under a joint GT $n - K$ security criterion: An adjustable robust optimization approach</p>	<p>Anthony Papavasiliou: Applying high performance computing to multi-area stochastic unit commitment for high wind penetration</p>	MA 549
<p>Optimization in energy systems: Unit commitment and inventory problems [p. 84] Ali Koc: Parallel branch-cut-price for solving multistage stochastic unit commitment problems</p>	<p>Tim Schulze: Decomposition methods for stochastic unit commitment</p>	MA 550
<p>PDE-constrained optimization and multi-level/multi-grid methods: Applications of PDE-constrained optimization [Organizer: Michael Ulbrich] [p. 84] Rene Pinnau: Exploiting model hierarchies in space mapping optimization</p>	<p>Michael Ulbrich: An adaptive semismooth Newton-CG method for constrained parameter identification in seismic tomography</p>	MA 415
<p>Robust optimization: Extensions of robust optimization models [p. 84] Michael Todd: A robust robust (sic) optimization result</p>	<p>Frank Pfeuffer: An extension of the controlled robustness model of Bertsimas and Sim</p>	H 3503
<p>Sparse optimization and compressed sensing: New models and algorithms in sparse optimization [Organizer: Benjamin Recht] [p. 85] Nicolas Boumal: Riemannian algorithms and estimation bounds for synchronization of rotations</p>	<p>Benjamin Recht: Atomic norm denoising with applications to spectrum estimation and system identification</p>	H 1028
<p>Stochastic optimization: Advances in stochastic optimization [Organizer: David Brown] [p. 85] David Brown: Optimal sequential exploration: Bandits, clairvoyants, and wildcats</p>	<p>Constantine Caramanis: Optimization at all levels: Probabilistic Envelope Constraints</p>	MA 141
<p>Stochastic optimization: Optimization of physical systems under uncertainty [Organizer: Mihai Anitescu] [p. 85] Victor Zavala: Stochastic optimization: Impacts on electricity markets and operations</p>	<p>Bernardo Pagnoncelli: The optimal harvesting problem under risk aversion</p>	MA 144
<p>Stochastic optimization: Decisions policies and estimation techniques in a stochastic environment [Organizer: Fabian Bastin] [p. 86] Alwin Haensele: A SP approach for decision-dependent uncertainty in production planning under non-compliance risk</p>	<p>Xinan Yang: Approximate dynamic programming with Bézier curves/surfaces for top-percentile traffic routing</p>	MA 376
<p>Telecommunications and networks: Optical access networks [Organizer: Andreas Bley] [p. 86] Cédric Hervet: Robust optimization of optical fiber access networks deployments</p>	<p>Olaf Maurer: Lagrangian approaches to a two-level FTTX network design problem</p>	H 3002
<p>Variational analysis: Nonsmooth phenomena in optimal control [Organizer: Roland Herzog] [p. 86] Christian Meyer: Boundary control of the obstacle problem</p>	<p>Frank Schmidt: Properties of the optimal value function and application to worst-case robust optimal control problems</p>	H 2035
<p>Variational analysis: Equilibrium problems and related topics [Organizer: Alfredo Iusem] [p. 87] Orizon Ferreira: Local convergence of Newton's method under majorant condition in Riemannian manifolds</p>	<p>Luis Drummond: New strategies for vector optimization problems</p>	H 2051
<p>Monday 13:15–14:45</p>		
<p>Approximation and online algorithms: Real-time scheduling [Organizer: Sanjoy Baruah] [p. 87] Martin Niermeier: Scheduling with an orthogonal resource constraint</p>	<p>Jian-Jia Chen: Resource augmentation in real-time systems</p>	H 3010

<p>Combinatorial optimization: Combinatorial optimization in chip design II [Organizer: Ulrich Brenner] [p. 87] Ulrike Suhl: Lagrangian relaxation and quadratic minimum cost flows for gate sizing</p>	<p>[Organizer: Ulrich Brenner] [p. 87] Christoph Bartoschek: Fast buffering of repeater trees</p>	<p>H 3004</p>
<p>Combinatorial optimization: Structural graph theory and methods [Organizer: Paul Wollan] [p. 88] Sang-Il Oum: Vertex-minors and pivot-minors of graphs</p>	<p>[Organizer: Paul Wollan] [p. 88] Gwenael Joret: Excluded forest minors and the Erdős-Pósa Property</p>	<p>H 3005</p>
<p>Combinatorial optimization: Discrete structures and algorithms I [Organizer: Satoru Fujishige] [p. 88] Shuji Kijima: Efficient randomized rounding in permutahedron</p>	<p>[Organizer: Satoru Fujishige] [p. 88] Júlia Pap: Characterizing and recognizing generalized polymatroids</p>	<p>H 3008</p>
<p>Combinatorial optimization: Scheduling I [p. 88] Thomas Rieger: Two variants of flexible job shop scheduling with blockages</p>	<p>Leen Stougie: Scheduling with job-splitting and fixed setup</p>	<p>H 3012</p>
<p>Combinatorial optimization: Recoverable robust combinatorial optimization [Organizer: Arie Koster] [p. 89] Christina Büsing: k-distance recoverable robustness</p>	<p>[Organizer: Arie Koster] [p. 89] Arie Koster: The recoverable robust knapsack problem</p>	<p>H 3013</p>
<p>Combinatorial optimization: Scheduling algorithms II [Organizer: Vincenzo Bonifaci] [p. 89] Cyril Ruten: Scheduling sporadic tasks on unrelated parallel machines</p>	<p>[Organizer: Vincenzo Bonifaci] [p. 89] Andreas Wiese: A new approach to online scheduling: Approximating the optimal competitive ratio</p>	<p>H 3021</p>
<p>Complementarity and variational inequalities: Game theoretic analysis and optimization for resource allocation in communication systems [Organizer: Zhi-Quan (Tom) Luo] [p. 89] Sławomir Stanczak: Progress and challenges in decentralized resource allocation optimization</p>	<p>[Organizer: Zhi-Quan (Tom) Luo] [p. 89] Gesualdo Scutari: Monotone communication games</p>	<p>MA 041</p>
<p>Complementarity and variational inequalities: Optimization and equilibrium problems I [Organizers: Christian Kanzow and Michael Ulbrich] [p. 90] Oliver Stein: On differentiability properties of player convex generalized Nash equilibrium problems</p>	<p>[Organizers: Christian Kanzow and Michael Ulbrich] [p. 90] Michael Ferris: Stochastic variational inequalities and MOPEC</p>	<p>MA 313</p>
<p>Conic programming: Algorithms for matrix optimization problems [p. 90] Qingna Li: Sequential semismooth Newton method for nearest low-rank correlation matrix problem</p>	<p>[p. 90] Chengjing Wang: On how to solve large scale matrix log-determinant optimization problems</p>	<p>H 2036</p>
<p>Conic programming: Nonlinear semidefinite programs and copositive programs [Organizer: Florian Jarre] [p. 90] Michal Kocvara: Introducing PENLAB, a Matlab code for nonlinear conic optimization</p>	<p>[Organizer: Florian Jarre] [p. 90] Mirjam Dür: Remarks on copositive plus matrices and the copositive plus completion problem</p>	<p>H 2038</p>
<p>Constraint programming: Improved representations for constraint programming [Organizers: Jean-Charles Régin and Michel Rueher] [p. 91] Willem-Jan van Hoeve: Applying decision diagrams to constraint optimization problems</p>	<p>[Organizers: Jean-Charles Régin and Michel Rueher] [p. 91] Charlotte Truchet: Octagonal domains for constraint programming</p>	<p>H 3003A</p>
<p>Finance and economics: New developments in computational finance [Organizer: Thomas Coleman] [p. 91] Thomas Coleman: On the use of automatic differentiation to efficiently determine first and second derivatives in financial applications</p>	<p>[Organizer: Thomas Coleman] [p. 91] Raquel Fonseca: Robust value-at-risk with linear policies</p>	<p>H 3027</p>
<p>Game theory: Large games and networks: Control and approachability [Organizer: Dario Bauso] [p. 91] Giacomo Como: Stability analysis of transportation networks with multiscale driver decisions</p>	<p>[Organizer: Dario Bauso] [p. 91] Dario Bauso: Time-averaged consensus and distributed approachability in large multi-agent networks</p>	<p>MA 043</p>
<p>Global optimization: Global optimization: Algorithms and applications [Organizer: Oleg Prokopyev] [p. 92] Steffen Rebennack: Good linear approximations for MINLP Problems with tolerance guarantee</p>	<p>[Organizer: Oleg Prokopyev] [p. 92] Oleg Prokopyev: Optimal design of the annual influenza vaccine with autonomous manufacturer</p>	<p>H 2053</p>
<p>Implementations and software: Optimization tools for R [Organizer: Erling Andersen] [p. 92] Henrik Friberg: The R-to-MOSEK optimization interface</p>	<p>[Organizer: Erling Andersen] [p. 92] Stefan Theussl: ROI – R Optimization Infrastructure package</p>	<p>H 1058</p>

Steven Dirkse: GDXXRW: Exchanging data between GAMS and R

<p>Integer and mixed-integer programming: MILP formulations I [p. 92] Laura McLay: A mixed-integer programming model for enforcing priority list policies in Markov decision processes</p>	<p>H 2013</p>
<p>Integer and mixed-integer programming: Integer programming algorithms II [p. 93] Serigne Gueye: Using distance variables for the quadratic assignment problem</p>	<p>H 2032</p>
<p>Integer and mixed-integer programming: New methodologies for mixed-integer programming [Organizer: Daniel Bienstock] [p. 93] Daniel Bienstock: Strong formulations for convex functions over nonconvex sets</p>	<p>MA 004</p>
<p>Integer and mixed-integer programming: Computational integer programming [Organizer: Ricardo Fukasawa] [p. 93] Franz Wesselmann: Computational experiments with general-purpose cutting planes</p>	<p>MA 042</p>
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<p>Logistics, traffic, and transportation: Branch-and-price algorithms in transportation [Organizers: Florian Dahms and Marco Lübbecke] [p. 94] Robert Voll: Branch-and-price-and-cut for railroad blocking plans Michel Seixas: Branch-and-price for a rich vehicle routing and scheduling problem</p>	<p>H 0106</p>
<p>Logistics, traffic, and transportation: Advances in machine learning [Organizer: Vivek Farias] [p. 94] Paul Grigas: Proximal subgradient and dual averaging for sequential decision-making and non-smooth optimization Vivek Farias: Non-parametric approximate dynamic programming via the kernel method</p>	<p>H 0111</p>
<p>Mixed-integer nonlinear programming: Global mixed-integer nonlinear optimization II [Organizer: Ignacio Grossmann] [p. 94] Braço Knudsen: Mixed integer optimization of the late-life performance of shale-gas wells Gonzalo Guillén-Gosálbez: Solving mixed-integer linear-fractional programming problems via an exact MILP reformulation</p>	<p>MA 005</p>
<p>Multi-objective optimization: Efficient set representations [Organizer: Luís Paquete] [p. 95] Michael Stiglmayr: The multicriteria linear bottleneck assignment problem Luís Paquete: Concise representation of nondominated sets in discrete multicriteria optimization</p>	<p>H 1029</p>
<p>Nonlinear programming: Methods for nonlinear optimization II [p. 95] Art Gorka: Parallel direction finding algorithm in method of feasible directions James Hungerford: Edge directions in polyhedral optimization</p>	<p>H 0107</p>
<p>Nonlinear programming: Nonlinear optimization II [Organizers: Frank E. Curtis and Daniel Robinson] [p. 96] Daniel Robinson: A primal-dual active-set method for convex QP Sven Leyffer: Large-scale nonlinear optimization solvers</p>	<p>H 0110</p>
<p>Nonlinear programming: Structures, complexities, and eigenvalues of tensor forms and polynomial functions [Organizer: Shuzhong Zhang] [p. 96] Shuzhong Zhang: Cones of nonnegative quartic polynomial functions and their applications Lek-Heng Lim: 3-tensors as the boundary of tractability</p>	<p>H 0112</p>
<p>Nonsmooth optimization: Constrained variational inequalities: Approximation and numerical resolution [Organizer: Juan Peyrouquet] [p. 96] Juan Peyrouquet: Lagrangian-penalization algorithm for constrained optimization and variational inequalities Yboon Garcia Ramos: Representable monotone operators and limits of sequences of maximal monotone operators</p>	<p>H 1012</p>
<p>Optimization in energy systems: Optimization in energy systems [Organizer: Jon Lee] [p. 97] Timo Lohmann: Stochastic hydro-thermal scheduling with CVaR risk constraints in deregulated markets Nicola Secomandi: Approximate linear programming relaxations for commodity storage real option management</p>	<p>MA 549</p>

<p>Optimization in energy systems: Network operation under failures and losses [p. 97] Richard Chen: Survivability-constrained generation unit commitment with post-contingency corrective recourse</p>	<p>Jose Canto dos Santos: New genetic algorithms for contingencies selection in electric power systems</p>	<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Iterative solution of PDE constrained optimization and subproblems [p. 97] Pavel Zhlobich: Multilevel quasiseparable matrices in PDE-constrained optimization</p>	<p>Gregor Kriwet: Covariance matrix computation for parameter estimation in nonlinear models solved by iterative linear algebra methods</p>	<p>MA 415</p>
<p>Robust optimization: Robust nonlinear optimization [p. 98] Martin Mevisen: Distributionally robust optimization for polynomial optimization problems</p>	<p>Hans Pirnay: An algorithm for robust optimization of nonlinear dynamic systems</p>	<p>H 3503</p>
<p>Sparse optimization and compressed sensing: Sparse optimization and generalized sparsity models [Organizer: Gitta Kutyniok] [p. 98] Rayan Saab: Recovering compressively sampled signals using partial support information</p>	<p>Emmanuel Candes: PhaseLift: Exact phase retrieval via convex programming</p>	<p>H 1028</p>
<p>Stochastic optimization: Applications in natural resources [p. 98] Gankhuyag Danzan: Regional economical mathematical models considering ecological factors</p>	<p>Ralf Lenz: Optimization of water network operation under uncertainties</p>	<p>MA 141</p>
<p>Stochastic optimization: Production, inventory and project management [p. 99] Wen-Lung Huang: Optimal aggregate production planning with fuzzy data</p>	<p>Ali Randa: Static-dynamic uncertainty strategy for a single-item stochastic inventory control problem</p>	<p>MA 144</p>
<p>Stochastic optimization: Stochastic mixed-integer programming [Organizer: Maarten van der Vlerk] [p. 99] LanaH Evers: The orienteering problem under uncertainty: Robust optimization and stochastic programming compared</p>	<p>Ward Romeijn: On the performance of a class of convex approximations for integer recourse models</p>	<p>MA 376</p>
<p>Telecommunications and networks: Wireless networks [p. 100] Sergey Astrakov: The full efficient monitoring of stripe with external deployment sensors</p>	<p>Ashutosh Nigam: A Lagrangian heuristic for delay constrained relay node placement problem in wireless sensor networks</p>	<p>H 3002</p>
<p>Variational analysis: Eigenvalue and semi-infinite optimization [p. 100] Sara Grundel: Variational analysis of the spectral abscissa for defective and derogatory matrices</p>	<p>Tatiana Tchemisova: On a constructive approach to optimality conditions for convex SIP problems with polyhedral index sets</p>	<p>H 2035</p>
<p>Variational analysis: Variational analysis and economic equilibrium [Organizer: Alejandro Jofré] [p. 100] Abderrahim Jourani: A characterization of the free disposal condition for nonconvex economies on infinite-dimensional commodity spaces</p>	<p>Alejandro Jofré: The robust stability of every equilibrium in economic models of exchange even under relaxed standard conditions</p>	<p>H 2051</p>
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<p>Approximation and online algorithms: Location and routing problems [p. 101] Tim Nonner: Polynomial-time approximation schemes for shortest path with alternatives</p>	<p>Artem Panin: On approximability some location and pricing problems</p>	<p>H 3010</p>
<p>Combinatorial optimization: Interactions between optimization and game theory in scheduling [Organizer: Neil Oliver] [p. 101] Marc Uetz: Mechanism design for single machine scheduling by ILP</p>	<p>Ruben Hoeksma: Price of anarchy for minsum related machine scheduling</p>	<p>H 3004</p>
<p>Combinatorial optimization: Exact and approximation algorithms on graphs [Organizer: Frédéric Meunier] [p. 101] Denis Cornaz: Strengthening Lovász bound for coloring with a new graph transformation</p>	<p>Henning Bruhn: Clique or hole in claw-free graphs</p>	<p>H 3005</p>

<p>Combinatorial optimization: Distances in graphs [Organizers: Christian Wulff-Nilsen and Glencora Borradaile] [p. 102] Rachit Agarwal: The space-stretch-time tradeoff in distance oracles</p>	<p>Liam Roditty: A survey on distance oracles</p>	<p>H 3008</p>
<p>Combinatorial optimization: Scheduling II [p. 102] Matthew Oster: A branch and cut algorithm for solving capacitated max k-cut with an application in scheduling</p>	<p>Alexander Tesch: Optimization of the ISMP 2012 schedule</p>	<p>H 3012</p>
<p>Combinatorial optimization: Constrained clustering [Organizer: Peter Gritzmann] [p. 102] Steffen Borgwardt: On the diameter of partition polytopes and vertex-disjoint cycle cover</p>	<p>Andreas Brieden: Constrained clustering with convex objective function</p>	<p>H 3013</p>
<p>Combinatorial optimization: Equilibria and combinatorial structures [Organizer: Britta Peis] [p. 102] Walter Kern: Cooperative games and fractional programming</p>	<p>Tom McCormick: A primal-dual algorithm for weighted abstract cut packing</p>	<p>H 3021</p>
<p>Complementarity and variational inequalities: Analysis and learning in variational inequalities [Organizer: Shu Lu] [p. 103] Hao Jiang: Learning parameters and equilibria in noise-corrupted Cournot games with misspecified price functions</p>	<p>Andreas Fischer: A framework for smooth and nonsmooth equations with nonisolated solutions</p>	<p>MA 041</p>
<p>Complementarity and variational inequalities: Optimization and equilibrium problems II [Organizers: Christian Kanzow and Michael Ulbrich] [p. 103] Sebastian Albrecht: Inverse optimal control of human locomotion</p>	<p>Christian Kanzow: Nash equilibrium multiobjective elliptic control problems</p>	<p>MA 313</p>
<p>Conic programming: Semidefinite programming applications [p. 103] Suryoung Kim: A successive SDP relaxation method for distance geometry problems</p>	<p>Tomohiko Mizutani: SDP relaxations for the concave cost transportation problem</p>	<p>H 2036</p>
<p>Conic programming: Matrix optimization [Organizer: Defeng Sun] [p. 104] Houdou Qi: Computing the nearest Euclidean distance matrix</p>	<p>Renato Monteiro: An accelerated hybrid proximal extragradient method for convex optimization and its implications to second-order methods</p>	<p>H 2038</p>
<p>Constraint programming: Constraint programming standard and industrial applications [Organizer: Narendra Jussien] [p. 104] Roberto Castaneda Lozano: Robust code generation using constraint programming</p>	<p>Abder Aggoun: Modelling and solving a class of combinatorial problems in supply chain using the Choco constraint programming system</p>	<p>H 3003A</p>
<p>Finance and economics: Risk management in finance and insurance [Organizer: Walter Farkas] [p. 104] Walter Farkas: Acceptability and risk measures: effectiveness, robustness and optimality</p>	<p>William Pouliot: Value-at-Risk</p>	<p>H 3027</p>
<p>Game theory: Design of optimal mechanisms [Organizer: Rudolf Müller] [p. 105] Maria Polukarov: Optimal payments in dominant-strategy mechanisms for single-parameter domains</p>	<p>Konrad Mierendorff: Generalized reduced-form auctions: A network-flow approach</p>	<p>MA 043</p>
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<p>Integer and mixed-integer programming: MILP formulations II [p. 106] Stefan Schmedder: Optimizing life cycle costs for buildings</p>	<p>Ali Fattahi: A novel integer programming formulation for U-shaped line balancing problems type-1</p>	<p>Rui Oliveira: Models for school networks planning</p>	<p>H 2013</p>
<p>Integer and mixed-integer programming: Trends in mixed integer programming [p. 107] Giacomo Nannicini: On the safety of Gomory cut generators</p>	<p>(Organizers: Andrea Lodi and Robert Weismantel) [p. 106] Utz-Uwe Haus: Split cuts for robust and generalized mixed-integer programming</p>	<p>Oktaý Gunluk: Lattice-free sets, branching disjunctions, and mixed-integer programming</p>	<p>H 2032</p>
<p>Integer and mixed-integer programming: Linear optimization [p. 107] Sergei Chubanov: An improved polynomial relaxation-type algorithm for linear programming</p>	<p>Roland Wunderling: The kernel simplex method</p>	<p>Angelo Sifaleras: Exterior point simplex-type algorithms for linear and network optimization problems</p>	<p>MA 042</p>
<p>Life sciences and healthcare: Therapy planning [p. 107] Åsa Holm: A new optimization model for brachytherapy dose plans</p>	<p>Rasmus Bokrantz: Multi-criteria optimization for volumetric-modulated arc therapy by convex decompositions</p>	<p>Laurenz Gollmann: Combination therapy considered as a multiple delayed optimal control problem</p>	<p>H 2033</p>
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<p>Logistics, traffic, and transportation: Network problems [p. 108] Thomas Kalinowski: Scheduling arc outages in networks to maximize total flow over time</p>	<p>Daniel Ferber: Incorporating temporal in-transit inventory into linear programming network flow models</p>	<p>Kwong Meng Teo: Solving network flow problems with general non-separable convex costs using a two-phase gradient projection algorithm</p>	<p>H 0111</p>
<p>Mixed-integer nonlinear programming: Tight relaxations (Organizer: Stefan Vigerske) [p. 108] Thomas Lehmann: On the efficient construction of disjunctive cutting planes for mixed-integer quadratic optimization problems</p>	<p>Dennis Michaels: The convex hull of vectors of functions</p>	<p>Ambros Gleixner: Rapid optimality-based bound tightening</p>	<p>MA 005</p>
<p>Multi-objective optimization: Multiobjective optimization (Organizer: Emilio Carrizosa) [p. 108] Antonio Flores-Tlacuahuac: An utopia-tracking approach to multiobjective predictive control</p>	<p>Włodzimierz Ogryczak: Fair multiobjective optimization: Models and techniques</p>	<p>Kai-Simon Goetzmann: Compromise solutions</p>	<p>H 1029</p>
<p>Nonlinear programming: Methods for nonlinear optimization III [p. 109] Yuan Shen: New augmented Lagrangian-based proximal point algorithms for convex optimization with equality constraint</p>	<p>Mehiddin Al-Baali: Hybrid damped-BFGS/Gauss-Newton methods for nonlinear least-squares</p>	<p>Masoud Ahookhosh: An improved nonmonotone technique for both line search and trust-region frameworks</p>	<p>H 0107</p>
<p>Nonlinear programming: Nonlinear optimization III (Organizers: Frank E. Curtis and Daniel Robinson) [p. 109] Mikhail Solodov: Convergence properties of augmented Lagrangian methods under the second-order sufficient optimality condition</p>	<p>Frank E. Curtis: Infeasibility detection in nonlinear optimization</p>	<p>Figen Oztoprak: Two-phase active set methods with applications to inverse covariance estimation</p>	<p>H 0110</p>
<p>Nonlinear programming: Unconstrained optimization I [p. 109] Saman Babaie-Kafaki: A modification on the Hager-Zhang conjugate gradient method</p>	<p>Tove Odland: On the relationship between quasi-Newton methods and the conjugate</p>	<p>Roummel Marcia: Limited-memory BFGS with diagonal updates</p>	<p>H 0112</p>
<p>Nonsmooth optimization: Nonsmooth optimization in imaging sciences I (Organizer: Gabriel Peyré) [p. 110] Gabriel Peyré: A review of proximal splitting methods with a new one</p>	<p>Thomas Pock: On parameter learning in variational models</p>	<p>Volkan Cevher: Nonconvex models with exact and approximate projections for constrained linear inverse problems</p>	<p>H 1012</p>
<p>Optimization in energy systems: Optimisation models for renewables integration (Organizers: Rodrigo Moreno and Luiz Barroso) [p. 110] Enzo Sauma: Transmission planning and generation response for integrating renewables</p>	<p>Álvaro Veiga: Backing up wind power firm contract sales on hydro generation with stochastic optimization: A Brazilian case study</p>	<p>Rodrigo Moreno: Transmission network operation and planning with probabilistic security to facilitate the connection of renewable generation</p>	<p>MA 549</p>

<p>Optimization in energy systems: Stochastic optimization for electricity production and trading [Organizer: Raimund Kovacevic] [p. 110] Denising Martin: Multistage stochastic optimization of power dispatch and multiperiod duality of CVaR Georg Pflug: Stochastic bilevel programs with applications to electricity contracts</p>	<p>Bitá Analui: Multistage stochastic optimization problems under model ambiguity</p>	<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Numerical methods in shape and topology optimization [Organizer: Antoine Laurain] [p. 111] Kevin Sturm: Shape optimization for an interface problem in linear elasticity for distortion compensation Volker Schulz: On the usage of the shape Hessian in aerodynamic shape optimization</p>	<p>(Organizer: Antoine Laurain) [p. 111]</p>	<p>MA 415</p>
<p>Robust optimization: Extensions of robust optimization approaches [p. 111] Phantipa Thipwattatjona: Pessimistic, optimistic, and minimax regret approaches for linear programs under uncertainty Michael Römer: Linear optimization with variable parameters: Robust and generalized linear programming and their relations</p>	<p>Mohammad Mehdi Nasrabadi: A fuzzy programming approach to robust optimization</p>	<p>H 3503</p>
<p>Robust optimization: Robust network optimization [Organizer: Ebrahim Nasrabadi] [p. 111] Sebastian Stiller: Robust network flows David Adijashvili: Fault-tolerant shortest paths – Beyond the uniform failure model</p>	<p>Ebrahim Nasrabadi: On the power of randomization in robust optimization</p>	<p>MA 004</p>
<p>Sparse optimization and compressed sensing: Global rate guarantees in sparse optimization [Organizer: Michel Baes] [p. 112] Wotao Yin: Augmented L1 and nuclear-norm minimization with a globally linearly convergent algorithm Lin Xiao: A proximal-gradient homotopy method for the sparse least-squares problem</p>	<p>Michel Baes: First-order methods for eigenvalue optimization</p>	<p>H 1028</p>
<p>Stochastic optimization: Solution methods for constrained stochastic optimization [Organizer: Sumit Kunnumkal] [p. 112] Lijian Chen: Solving chance-constrained optimization by Bernstein polynomial approximation Sumit Kunnumkal: Randomization approaches for network RM with choice behavior</p>	<p>Gabor Rudolf: Optimization with multivariate conditional-value-at-risk constraints</p>	<p>MA 141</p>
<p>Stochastic optimization: Approximation algorithms for stochastic revenue management optimization [Organizer: Retsef Levi] [p. 112] Retsef Levi: Near-optimal algorithms for assortment planning under dynamic substitution and stochastic demand Dragos Ciocan: Dynamic allocation problems with volatile demand</p>	<p>Cong Shi: Revenue management of reusable resources with advanced reservations</p>	<p>MA 144</p>
<p>Stochastic optimization: Advances in probabilistically constrained optimization [Organizer: Miguel Lejeune] [p. 113] Miguel Lejeune: Threshold boolean form for the reformulation of joint probabilistic constraints with random technology matrix Ahmed Shabbir: Probabilistic set covering with correlations</p>	<p>Pavlo Krokmal: On polyhedral approximations in p-order conic programming</p>	<p>MA 376</p>
<p>Telecommunications and networks: Optimization of optical networks [Organizer: Brigitte Jaumard] [p. 113] Brigitte Jaumard: Path vs. cutset column generation models for the design of IP-over-WDM optical networks Jørgen Haahr: Heuristic planning of shared backup path protection</p>	<p>Philippe Mahey: Algorithms for lower and upper bounds for routing and wavelength assignment</p>	<p>H 3002</p>
<p>Variational analysis: Lower order exact penalty functions [Organizer: Xiaoqi Yang] [p. 113] Xiaoqi Yang: Optimality conditions via exact penalty functions Boshi Tian: An interior-point $\ell_{1/2}$-penalty method for nonlinear programming</p>	<p>Zhangyou Chen: Exact penalty functions for semi-infinite programming</p>	<p>H 2035</p>
<p>Variational analysis: Some applications of variational analysis [Organizer: Nguyen Dong Yen] [p. 114] Mau Nam Nguyen: Variational analysis of minimal time functions with unbounded dynamics and generalized smallest enclosing circle problems Andrew Eberhard: Approaches to optimality conditions using nonsmooth and variational methods</p>	<p>Gue Myung Lee: On constraint qualifications for mathematical programs with equilibrium constraints</p>	<p>H 2051</p>
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<p>Approximation and online algorithms: Approximation in algorithmic game theory [Organizer: Chaitanya Swamy] [p. 114] Konstantinos Georgiou: Black-box reductions for cost-sharing mechanism design Berthold Vöcking: A universally-truthful approximation scheme for multi-unit auctions</p>	<p>Deeparnab Chakrabarty: Matching markets with ordinal preferences</p>	<p>H 3010</p>
<p>Combinatorial optimization: Generalizing shortest paths, cycles, and Steiner trees [p. 114] Stefano Gualandri: Resource constrained shortest paths with a super additive objective function Hiroshige Dan: Finding the shortest cycle in directed graphs under some constraints on passing vertices and paths</p>	<p>Marika Karbstein: Approximation and min-max results for the Steiner connectivity problem</p>	<p>H 3004</p>

<p>Combinatorial optimization: Submodularity and covering [Organizer: Jon Lee] [p. 115] Maxim Swiridenko: New and improved bounds for the minimum set cover problem</p>	<p>[Organizer: Andreas Krause: Adaptive submodularity: Theory and applications in active learning and stochastic optimization]</p>	<p>H 3005</p>
<p>Combinatorial optimization: LP based approximation algorithms for location and routing [Organizer: Viswanath Nagarajan] [p. 115] Jaroslaw Byrka: Fault-tolerant facility location: A randomized dependent LP-rounding algorithm</p>	<p>[Organizer: Anna Blasiak: Improved approximation algorithms for the minimum latency problem via prize-collecting paths]</p>	<p>H 3008</p>
<p>Combinatorial optimization: Scheduling III [p. 116] Evgeny Gafarov: Two-station single track railway scheduling problem with equal speed of trains</p>	<p>[Organizer: Jens Poppenberg: Modeling the resource-constrained project scheduling problem with resource transfers using a graph approach.]</p>	<p>H 3012</p>
<p>Combinatorial optimization: Trees and words [p. 116] Winfried Hochstättler: Some heuristics for the binary paint shop problem and their expected number of colour changes</p>	<p>[Organizer: Marcin Krzywkowski: An algorithm listing all minimal dominating sets of a tree]</p>	<p>H 3013</p>
<p>Combinatorial optimization: Data structures and algorithms for VLSI routing [Organizer: Tim Nieberg] [p. 116] Dirk Müller: Multi-flows and generalizations in VLSI routing</p>	<p>[Organizer: Christian Schulte: Efficient algorithms and data structures in VLSI detailed routing]</p>	<p>H 3021</p>
<p>Complementarity and variational inequalities: Complementarity properties of linear transformations on Euclidean Jordan algebras [Organizer: Jiyuan Tao] [p. 117] Jeyaraman Irulappasamy: P and semimonotonicity properties of linear transformations on Euclidean Jordan algebras</p>	<p>[Organizer: Roman Sznajder: Complementarity properties of linear transformations on product spaces via Schur complements]</p>	<p>MA 041</p>
<p>Complementarity and variational inequalities: Matrix classes for linear complementarity problems [Organizer: Todd Munson] [p. 117] Todd Munson: Preprocessing with composite matrices</p>	<p>[Organizer: Richard Cottle: Lemke's algorithms and matrix classes for the linear complementarity problem]</p>	<p>MA 313</p>
<p>Conic programming: Smoothing methods for symmetric cone complementarity problems [p. 117] Cong Cheng: A smoothing method for symmetric cone complementarity problems</p>	<p>[Organizer: Ellen Fukuda: Differentiable exact penalty functions for nonlinear second-order cone programs]</p>	<p>H 2036</p>
<p>Conic programming: New advances in conic programming [Organizer: Cristian Dobre] [p. 117] Julia Sponset: On standard quadratic optimization problems</p>	<p>[Organizer: Cristian Dobre: Infinite dimensional semidefinite programming]</p>	<p>H 2038</p>
<p>Constraint programming: Constraint programming for routing and scheduling [Organizer: Louis-Martin Rousseau] [p. 118] Jean-Guillaume Fages: Solving the traveling salesman problem with constraint programming</p>	<p>[Organizer: Arnaud Malapert: Scheduling a batch processing machine with constraints]</p>	<p>H 3003A</p>
<p>Derivative-free and simulation-based optimization: Derivative-free optimization and constraints [Organizers: Stefan Wild and Luís Nunes Vicente] [p. 118] Giovanni Fasano: An exact penalty method for constrained Lipschitz optimization</p>	<p>[Organizer: Kevin Kofler: Derivative-free optimization with equality constraints using data analysis]</p>	<p>H 3503</p>
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<p>Game theory: Game-theoretic models in operations [Organizer: Ilan Lobel] [p. 119] Ilan Lobel: Intertemporal price discrimination: Structure and computation of optimal policies</p>	<p>[Organizer: Hamid Nazerzadeh: Buy-it-now or take-a-chance: A mechanism for real-time price discrimination]</p>	<p>MA 043</p>
<p>Global optimization: Convex optimization approaches to polynomial optimization problems [Organizer: Miguel Anjos] [p. 119] Amélie Lambert: Convex reformulations of integer quadratically constrained problems</p>	<p>[Organizer: Franz Rendl: Active set methods for convex quadratic optimization with simple bounds]</p>	<p>H 2053</p>
<p>Implementations and software: MILP software II [Organizer: Thorsten Koch] [p. 119] Martin Tieves: Creating synergies between MIP-solvers</p>	<p>[Organizer: Michael Joswig: Polymake for integer linear programming]</p>	<p>H 1058</p>
<p>Rico Zenklusen: Matroids and integrality gaps for hypergraphic Steiner tree relaxations</p>	<p>Zachary Friggstad: A logarithmic approximation for the directed latency problem</p>	<p>H 3005</p>
<p>Sandro Bosio: Mailroom production planning</p>	<p>Yasuko Matsui: An enumeration algorithm for the optimal cost vertex-colorings for trees</p>	<p>H 3012</p>
<p>Michael Geester: New challenges in chip design driven by technology scaling</p>	<p>Gabriele Uchida: Think completely positive! Algebraic properties of matrices belonging to the copositive or related cones</p>	<p>H 3021</p>
<p>Shunsuke Hayashi: A smoothing SQP method for mathematical programs with second-order cone complementarity constraints</p>	<p>Juan Vera: Exploiting symmetry in copositive programs</p>	<p>H 2036</p>
<p>Louis-Martin Rousseau: Formal language for retail store workforce scheduling</p>	<p>Mjd Powell: On derivative-free optimization with linear constraints</p>	<p>H 3003A</p>
<p>Romy Shioda: Factor alignment problem in quantitative portfolio management</p>	<p>Georgia Perakis: Markdown optimization for a fashion e-tailer: The impact of returning customers</p>	<p>H 3027</p>
<p>Janez Povh: On the set-semidefinite representation of nonconvex quadratic programs over arbitrary feasible sets</p>	<p>Frédéric Gardi: LocalSolver: A mathematical programming solver based on local search</p>	<p>H 1058</p>

Integer and mixed-integer programming: MILP formulations III [p. 120] Ramiro Torres: Optimizing the Ecuadorian football league third division.	Keisuke Hotta: Enumeration and characterization of the electoral districting for the decision support	Magnus Önnheim: The opportunistic replacement problem: Model, theory and numerics	H 2013
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Logistics, traffic, and transportation: Routing with time windows [p. 121] Juan Otero: A hybrid evolutionary approach for solving the vehicle routing problem with time windows (VRPTW)	Tiago Montanher: An integer programming model for the oil transference in refineries under time window constraints	Paul Stursberg: Vehicle routing with flexible load carriers	H 0106
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Nonsmooth optimization: Nonsmooth optimization in imaging sciences II [Organizer: Dirk Lorenz] [p. 123] Michael Goldman: Continuous primal-dual methods for image processing	Elias Helou: Incremental subgradients for constrained convex optimization: A unified framework and new methods	Jerome Fehrenbach: Stripes removal in images, applications in microscopy	H 1012
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<p>Combinatorial optimization: Lift-and-project methods for combinatorial optimization problems [Organizer: Konstantinos Georgiou] [p. 129] Eden Chlamtac: Reduced integrality gaps and improved approximations via lift-and-project methods</p>	<p>H 3005</p>

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Combinatorial optimization: Matching and related problems [Organizer: Gyula Pap] [p. 129] Kristóf Bérczi: Restricted b -matchings	David Hartvigsen: A generalized k -matching problem	H 3013
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Constraint programming: CP hybrids for scheduling [Organizer: Chris Beck] [p. 131] Michele Lombardi: Hybrid off-line/on-line workload scheduling via machine learning and constraint programming	Thibaut Feydy: Lazy clause generation for RCPSP	H 3003A
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Finance and economics: Financial optimization [Organizer: Yuying Li] [p. 132] Yuying Li: A novel method for computing an optimal VaR portfolio	Somayeh Moazeni: Regularized robust optimization for optimal portfolio execution	H 3027
Game theory: Coordination mechanisms for efficient equilibria [Organizer: Tobias Harks] [p. 132] Laurent Gourves: On the price of anarchy of the set cover game	Martin Gairing: Coordination mechanisms for congestion games	MA 043
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Optimization in energy systems: Stochastic programming models for electricity generation planning [Organizer: Michel Gendreau] [p. 137] Oscar Carreno: Developing optimization software for Colombian power system planning Raphael Gonçalves: Analyzing multistage stochastic optimization methods to solve the operation planning problem of hydrothermal systems Michel Gendreau: Midterm hydro generation scheduling under inflow uncertainty using the progressive hedging algorithm	MA 550
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Sparse optimization and compressed sensing: Coordinate descent methods for huge-scale optimization [Organizer: Peter Richtarik] [p. 139] Peter Richtarik: Parallel block coordinate descent methods for huge-scale partially separable problems Martin Takac: Distributed block coordinate descent method: iteration complexity and efficient hybrid implementation	Rachael Tappenden: Block coordinate descent method for block-structured problems	H 1028
Stochastic optimization: Stochastic optimization – confidence sets, stability, robustness [Organizer: Petr Lachout] [p. 139] Silvia Vogel: Confidence regions for level sets – Sufficient conditions	Milos Kopa: Robustness in stochastic programs with risk and probabilistic constraints	MA 141
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Stochastic optimization: Computational aspects of stochastic integer programming for large-scale and/or real-world problems [Organizer: Jörg Rambau] [p. 140] Jonas Schweiger: Multi-scenario topology optimization in gas networks Miriam Kiefling: ISPO – Integrated size and price optimization for a fashion discounter with many branches	Konrad Schade: The stochastic guaranteed service model	MA 376
Telecommunications and networks: Tree problems [Organizer: Ivana Ljubic] [p. 140] Bernd Zey: The stochastic Steiner tree problem: Models and solution strategies	Subramanian Raghavan: Recoverable robust two level network design	H 3002
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Combinatorial optimization: LP relaxations [p. 143] Maria Teresa Godinho: On a time-dependent formulation for the travelling salesman problem	Yong-Hong Kuo: On the mixed set covering, partitioning and packing problem	H 3012

<p>Combinatorial optimization: Combinatorial optimization and equilibria for flows over time [Organizers: Neil Olver and Jose Correa] [p. 143] Lisa Fleischer: Competitive strategies for routing flow over time Omar Larre: Existence and uniqueness of equilibria for flows over time</p>	<p>[p. 143] Ronald Koch: Continuous and discrete flows over time</p>	<p>H 3013</p>
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<p>Constraint programming: Constraint programming methodology [p. 145] Toby Walsh: Breaking variable and value symmetry in constraint satisfaction and optimisation problems</p>	<p>[p. 145] Burak Gokgur: Mathematical modelling and constraint programming approaches for operation assignment and tool loading problems in flexible manufacturing systems</p>	<p>H 3003A</p>
<p>Derivative-free and simulation-based optimization: Novel approaches in derivative-free optimization [Organizers: Luís Nunes Vicente and Stefan Wild] [p. 145] Yuri Nesterov: Random gradient-free minimization of convex functions</p>	<p>[p. 145] Alexander Rakhlin: Regret minimization with zeroth order information</p>	<p>H 3503</p>
<p>Finance and economics: Applications and algorithms [p. 146] Emilie Ioannopoulos: Feeding cost optimization of several diet formulations and environmental impact in the swine industry</p>	<p>[p. 146] Galina Yakulina: Project risks analysis using approach of fuzzy sets theory</p>	<p>H 3027</p>
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<p>Global optimization: From quadratic through factorable to black-box global optimization [Organizer: Leo Liberti] [p. 146] Laurent Dumas: A new global optimization method based on a sparse grid metamodel</p>	<p>[p. 146] Angelos Tsoukalas: Extension of McCormick's composition to multi-variate outer functions</p>	<p>H 2053</p>
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<p>Nonlinear programming: Real-time optimization III [Organizers: Victor Zavala and Sebastian Sager] [p. 150] Markus Kögel: On real-time optimization for model predictive control using multiplier methods and Nesterov's gradient method</p>	<p>Anatoli Juditsky [p. 150] Guanghai Lan: Stochastic first- and zero-order methods for nonconvex stochastic programming</p>	<p>Naiyuan Chiang: Solving SCOPF problems by a new structure exploiting interior point method</p>	<p>H 0112</p>
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<p>Optimization in energy systems: Optimization for power grids [Organizers: Arvind Raghunathan and Victor Zavala] [p. 151] Arvind Raghunathan: Global optimization of power flow problems</p>	<p>Marc Steinbach [p. 151] Bernhard Wiltert: A high accuracy optimization model for gas networks</p>	<p>Irwin Yousept: PDE-constrained optimization involving eddy current equations</p>	<p>MA 549</p>
<p>Optimization in energy systems: Mathematical optimization for mid-term operation planning in gas networks [Organizer: Marc Steinbach] [p. 151] Björn Geißler: A new approach for solving MINLPs applied to gas network optimization</p>	<p>Dietmar Hömberg [p. 151] Martin Grepl: A certified reduced basis approach for parametrized linear-quadratic optimal control problems</p>	<p>Nathan Kallus: The power of optimization over randomization in designing controlled trials</p>	<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Optimization applications in industry II [Organizer: Dietmar Hömberg] [p. 151] Stefan Ulbrich: Multilevel optimization based on adaptive discretizations and reduced order models for engineering applications</p>	<p>Allison O'Hair [p. 152] Andy Sun: Adaptive robust optimization for the security constrained unit commitment problem</p>	<p></p>	<p>MA 415</p>
<p>Robust optimization: Applications of robust optimization II [Organizer: Allison O'Hair] [p. 152] Allison O'Hair: Adaptive, dynamic and robust optimization to learn human preferences</p>	<p></p>	<p></p>	<p>MA 004</p>

<p>Robust optimization: Theory of robust optimization (Organizer: Dick Den Hertog) [p. 152] Dick Den Hertog: Deriving robust counterparts of nonlinear uncertain inequalities Bram Gorissen: Intractable robust counterparts of linear conic optimization problems via their duals</p>	<p>Ulrich Pferschy: On the robust knapsack problem</p>	<p>MA 042</p>
<p>Sparse optimization and compressed sensing: Algorithms for sparse optimization I (Organizer: Andreas Tillmann) [p. 152] Andreas Tillmann: Heuristic optimality check and computational solver comparison for basis pursuit of filter networks Spartak Zikrin: Sparse optimization techniques for solving multilinear least-squares problems with application to design of filter networks</p>	<p>Maxim Demenkov: Real-time linear inverse problem and control allocation in technical systems</p>	<p>H 1028</p>
<p>Stochastic optimization: Advances in stochastic programming (Organizer: Daniel Kuhn) [p. 153] Angelos Georgioul: A stochastic capacity expansion model for the UK energy system Kathrin Klamroth: Modeling uncertainties in location-allocation problems: A stochastic programming approach</p>	<p>Daniel Kuhn: Polyhedrality in distributionally robust optimization Marcus Poggi: On a class of stochastic programs with endogenous uncertainty: Algorithm and applications</p>	<p>MA 141 MA 144</p>
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<p>Telecommunications and networks: Communication network design [p. 154] Marc Ruiz: Multi-constructive meta-heuristic for the metro areas design problem in hierarchical optical transport networks Jonad Pulaj: Models for network design under varied demand structures</p>	<p>Youngho Lee: A nonlinear mixed integer programming problem in designing local access networks with QoS constraints.</p>	<p>H 3002</p>
<p>Variational analysis: Control and optimization of impulsive systems 2 (Organizers: Dmitry Karamzin and Fernando Pereira) [p. 154] Aram Arutyunov: The R.V. Gamkrelidze's Maximum Principle for state constrained optimal control problem: Revisited</p>	<p>Laurent Pfeiffer: Sensitivity analysis for relaxed optimal control problems with final-state constraints</p>	<p>H 2035</p>
<p>Variational analysis: Recent advances on linear complementarity problems (Organizer: Héctor Ramírez) [p. 155] Julio Lopez: Characterizing Q-linear transformations for linear complementarity problems over symmetric cones Jean-Baptiste Hiriart-Urruty: A variational approach of the rank function</p>	<p>Héctor Ramírez: Existence and stability results based on asymptotic analysis for semidefinite linear complementarity problems</p>	<p>H 2051</p>
<p>Wednesday 10:30–12:00</p>		
<p>Approximation and online algorithms: Scheduling and packing: Approximation with algorithmic game theory in mind (Organizer: Asaf Levin) [p. 155] Leah Epstein: Generalized selfish bin packing</p>	<p>Rob van Stee: The price of anarchy for selfish ring routing is two</p>	<p>H 3010</p>
<p>Combinatorial optimization: Extended formulations in discrete optimization II (Organizers: Gautier Stauffer and Volker Kaibel) [p. 156] Mathieu Van Vyve: Projecting an extended formulation</p>	<p>Dirk Oliver Theis: Some lower bounds on sizes of positive semidefinite extended formulations</p>	<p>H 3004</p>
<p>Combinatorial optimization: Algorithm for matrices and matroids [p. 156] Matthias Walter: A simple algorithm for testing total unimodularity of matrices</p>	<p>Leonidas Pitsoulis: Decomposition of binary signed-graphic matroids</p>	<p>H 3005</p>
<p>Combinatorial optimization: Combinatorics and geometry of linear optimization III (Organizers: Jesus De Loera and Antoine Deza) [p. 156] Shinji Mizuno: An upper bound for the number of different solutions generated by the primal-simplex method with any selection rule of entering variables</p>	<p>Uri Zwick: Subexponential lower bounds for randomized pivoting rules for the Simplex algorithm</p>	<p>H 3008</p>

Combinatorial optimization: Heuristics I [p. 157] Badri Toppur: A divide-and-bridge heuristic for Steiner minimal trees on the Euclidean plane	Yuri Frota: Upper and lower bounds for the constrained forest problem	Shunji Umetani: A heuristic algorithm for the set multicover problem with generalized upper bound constraints	H 3012
Combinatorial optimization: Network flows [p. 157] Maria Afsharid: Maximum dynamic flow interdiction problem	Andreas Karrenbauer: Planar min-cost flow in nearly $O(n^{3/2})$	Chandra Chekuri: Multicommodity flows and cuts in polymatroidal networks	H 3013
Combinatorial optimization: Routing for public transportation [Organizer: Peter Sanders] [p. 157] Matthias Müller-Hannemann: Coping with delays: Online timetable information and passenger-oriented train disposition	Thomas Pajor: Round-based public transit routing	Hannah Bast: Next-generation route planning: Multi-modal, real-time, personalized	H 3021
Complementarity and variational inequalities: Complementarity modeling and its game theoretical applications [Organizer: Samir Neogy] [p. 158] Samir Neogy: Generalized principal pivot transforms, complementarity problem and its applications in game theory	Abhijit Gupta: Complementarity model for a mixture class of stochastic game	Arun Das: A complementarity approach for solving two classes of undiscounted structured stochastic games	MA 041
Complementarity and variational inequalities: Advances in the theory of complementarity and related problems I [p. 158] Jain-Shan Chen: Lipschitz continuity of solution mapping of symmetric cone complementarity problem	Alexey Kurennoy: On regularity conditions for complementarity problems	Chandrashekar Arumugasamy: Some new results on semidefinite linear complementarity problems	MA 313
Conic programming: New conic optimization approaches for max-cut and graph equipartition [Organizer: Miguel Anjos] [p. 158] Nathan Krislock: Improved semidefinite bounding procedure for solving max-cut problems to optimality	Andreas Schmutzer: Branch-and-cut for the graph 2-equipartition problem	Angelika Wiegele: Lasserre hierarchy for max-cut from a computational point of view	H 2036
Conic programming: Conic and convex programming in statistics and signal processing II [Organizer: Venkat Chandrasekaran] [p. 159] Rachel Ward: Robust image recovery via total-variation minimization	Joel Tropp: Sharp recovery bounds for convex deconvolution, with applications	Parikshit Shah: Group symmetry and covariance regularization	H 2038
Constraint programming: Modeling and reformulation [Organizer: Mark Wallace] [p. 159] Mark Wallace: Inferring properties of models from properties of small instances	Helmut Simonis: Building global constraint models from positive examples	Ian Migue: Towards automated constraint modelling with essence and conjure	H 3003A
Derivative-free and simulation-based optimization: Exploiting structure in derivative-free optimization [Organizers: Luis Nunes Vicente and Stefan Wild] [p. 159] Carl Kelley: Sparse interpolatory models for molecular dynamics	Warren Hare: Derivative free optimization for finite minimax functions	Rommel Regis: A derivative-free trust-region algorithm for constrained, expensive black-box optimization using radial basis functions	H 3503
Finance and economics: Price dynamics in energy markets [Organizer: Florentina Paraschiv] [p. 160] Péter Erdős: Have oil and gas prices got separated?	Michael Schuerle: Price dynamics in gas markets	Florentina Paraschiv: Modelling negative electricity prices	H 3027
Game theory: Games over networks [Organizer: Asu Ozdaglar] [p. 160] Asu Ozdaglar: Network security and contagion	Pablo Parrilo: Near-potential network games	Ali Jadbabaie: A game-theoretic model of competitive contagion and product adoption in social networks	MA 005
Game theory: Variational inequalities in games [p. 160] Evgeniy Golshtein: Many-person games with convex structure	Vikas Jain: Constrained vector-valued dynamic game and symmetric duality for multiobjective variational problems	MA 043	
Global optimization: Optimal hybrid control theory approaches to global optimization [Organizer: Zelda Zabinsky] [p. 161] Zelda Zabinsky: Solving non-linear discrete optimization problems via continualization: An interior-point algorithm	Wolf Kohn: Hybrid dynamic programming for rule constrained multi-objective optimization	Pengbo Zhang: Stochastic control optimization of a binary integer program	H 2053
Implementations and software: Implementations of interior point methods for linear and conic optimization problems [Organizer: Erling Andersen] [p. 161] Csaba Meszaros: Exploiting hardware capabilities in implementations of interior point methods	Erling Andersen: On recent improvements in the interior-point optimizer in MOSEK	Imre Polik: Crossing over	H 1058
Integer and mixed-integer programming: Scheduling I [p. 161] Hesham Alfaris: Integer programming model and optimum solution for a bi-objective days-off scheduling problem	Andy Felt: MILP model for athletic conference scheduling	Andrea Raith: Minimising tardiness in parallel machine scheduling with setup times and mould type restrictions	H 2013

Integer and mixed-integer programming: Trends in mixed integer programming IV [Organizers: Robert Weismantel and Andrea Lodi] [p. 162] François Soumis: Integral simplex using decomposition guitoline cutting stock problems	Friedrich Eisenbrand: On bin packing, the MIRUP conjecture and discrepancy theory	H 2032
Integer and mixed-integer programming: Assignments and partitioning [p. 162] Ya Ju Fan: A heuristic for the local region covering problem	Trivikram Dokka: Fast separation algorithms for multi-dimensional assignment problems	H 2033
Logistics, traffic, and transportation: Vehicle routing and logistics optimization [Organizer: Daniele Vigo] [p. 162] Mario Ruthmair: An adaptive layers framework for vehicle routing problems	Daniele Vigo: An exact approach for the clustered vehicle routing problem	H 0106
Logistics, traffic, and transportation: Stochastic routing [Organizer: Pieter Audenaert] [p. 163] Sofie Demeyer: Time-dependent stochastic routing: A practical implementation	Sebastien Blandin: Fast computation of solution to stochastic on-time arrival problem	H 0111
Mixed-integer nonlinear programming: Topics in mixed-integer nonlinear programming I [p. 163] Laura Galli: Reformulating mixed-integer quadratically constrained quadratic programs	Anita Schöbel: A geometric branch and bound approach for nonlinear mixed-integer optimization	MA 042
Multi-objective optimization: Vector pareto analysis [Organizer: Henri Bonnel] [p. 163] Jacqueline Morgan: Semivectorial bilevel convex optimal control problems: Existence results	Julien Collonge: Optimization over the Pareto set associated with a multi-objective stochastic convex optimization problem	H 1029
Nonlinear programming: Regularization techniques in optimization I [Organizer: Jacek Gondzio] [p. 164] Jacek Gondzio: Recent advances in the matrix-free interior point method	Michael Saunders: QPBLUR: A regularized active-set method for sparse convex quadratic programming	H 0107
Nonlinear programming: Trust-region methods and nonlinear programming [Organizers: Henry Wolkowicz and Ting Kei Pong] [p. 164] Ya-xiang Yuan: Optimality conditions and smoothing trust region newton method for non-lipschitz optimization	Yuen-Lam Yris Cheung: Solving a class of quadratically constrained semidefinite programming problems with application to structure based drug design problem	H 0110
Nonlinear programming: Solution methods for matrix, polynomial, and tensor optimization [Organizer: Shuzhong Zhang] [p. 164] Xin Liu: Beyond heuristics: Applying alternating direction method of multiplier method in solving matrix factorization problems	Zheng-Hai Huang: An iterative algorithm for tensor n -rank minimization	H 0112
Nonsmooth optimization: Recent advances in optimization methods [Organizer: Marc Teboulle] [p. 165] Jérôme Bolte: Forward-backward splitting and other descent methods for semi-algebraic minimization problems	Marc Teboulle: Nonsmooth convex minimization: To smooth or not to smooth?	H 1012
Optimization in energy systems: Games, energy and investment [Organizer: René Aid] [p. 165] Vincent Leclère: The priority option: The value of being a leader in complete and incomplete markets	Imen Ben Tahar: Integration of an intermittent energy: A mean fields game approach	MA 549
Optimization in energy systems: Optimization in the oil & natural gas industry [Organizers: Bruno Flach and Luiz Barroso] [p. 165] Jorge Zubbelli: Evaluation of LNG contracts with cancellation options	Bruno Flach: An MIQP approach to the determination of analogous reservoirs	MA 550
PDE-constrained optimization and multi-level/multi-grid methods: Optimization applications in industry III [Organizer: Dietmar Hömberg] [p. 166] Roland Herzog: Optimal control of elastoplastic processes	Michael Stingl: Material optimization: From theory to practice	MA 415
Robust optimization: Applications of robust optimization III [Organizer: Aurelie Thiele] [p. 166] Elcin Cetinkaya: Robust customized pricing	Slawomir Pietrasz: Strategically robust investments on gas transmission networks	MA 004

<p>Sparse optimization and compressed sensing: Algorithms for sparse optimization II [Organizer: Kimon Fountoulakis] [p. 166] Xiangfeng Wang: Linearized alternating direction methods for Dantzig selector</p>	Sergey Voronin: Iteratively reweighted least squares methods for structured sparse regularization	H 1028
<p>Stochastic optimization: Algorithms for stochastic optimization and approximation [Organizer: Marc Steinbach] [p. 167] Jens Hübner: Structure-exploiting parallel interior point method for multistage stochastic programs</p>	Anthony Man-Cho So: Chance-constrained linear matrix inequalities with dependent perturbations: A safe tractable approximation approach	MA 141
<p>Stochastic optimization: Scheduling, control and moment problems [p. 167] Regina Hildibrandt: Partitions-requirements-matrices as optimal Markov kernels of special stochastic dynamic distance optimal partitioning problems</p>	Mariya Naumova: Univariate discrete moment problem for new classes of objective function and its applications	MA 144
<p>Stochastic optimization: Risk aversion in stochastic combinatorial optimization [Organizer: Evdokia Nikolova] [p. 167] Chaitanya Swamy: Risk-averse stochastic optimization: Probabilistically-constrained models and algorithms for black-box distributions</p>	Abraham Othman: Inventory-based versus prior-based options trading agents	MA 376
<p>Telecommunications and networks: Network flows and network design [Organizer: Bernard Fortz] [p. 168] Bernard Fortz: The hop-constrained survivable network design problem with reliable edges</p>	Edoardo Amaldi: Network routing subject to max-min fair flow allocation	H 3002
<p>Variational analysis: Nonsmooth variational inequalities: Theory and algorithms [Organizer: Russell Luke] [p. 168] Shoham Sabach: A first order method for finding minimal norm-like solutions of convex optimization problems</p>	Charitha Cherugondi: A descent method for solving an equilibrium problem based on generalized D-gap function	H 2035
<p>Variational analysis: Quadratic and polynomial optimization [Organizer: Jeya Jeyakumar] [p. 169] Gwi Soo Kim: On ϵ-saddle point theorems for robust convex optimization problems</p>	Guoyin Li: Error bound for classes of polynomial systems and its applications: A variational analysis approach	H 2051
<p>Wednesday 13:15–14:45</p>		
<p>Approximation and online algorithms: Approximation in routing and scheduling [Organizers: Nicole Megow and Jose Correa] [p. 169] Jose Verschae: The power of recourse for online MST and TSP</p>	Claudio Telha: The jump number (maximum independent set) of two-directional orthogonal-ray graphs	H 3010
<p>Combinatorial optimization: Extended formulations in discrete optimization III [Organizers: Volker Kaibel and Samuel Fiorini] [p. 169] Michele Conforti: Extended formulations in mixed-integer programming</p>	Giacomo Zambelli: Mixed-integer bipartite vertex covers and mixing sets	H 3004
<p>Combinatorial optimization: Geometric combinatorial optimization [p. 170] Eranda Dragoti-Cela: On the x-and-y axes travelling salesman problem</p>	Rafael Barbosa: Algorithms for the restricted strip cover problem	H 3005
<p>Combinatorial optimization: Combinatorics and geometry of linear optimization IV [Organizer: Friedrich Eisenbrand] [p. 170] Marco Di Summa: A new bound on the diameter of polyhedra</p>	Edward Kim: Subset partition graphs and an approach to the linear Hirsch conjecture	H 3008
<p>Combinatorial optimization: Heuristics II [p. 170] Salim Bouamama: A population-based iterated greedy algorithm for the minimum weight vertex cover problem</p>		H 3012
<p>Combinatorial optimization: Assignment problems [p. 171] Geir Dahl: Generalized Birkhoff polytopes and majorization</p>	Olga Heismann: The hypergraph assignment problem	H 3013

Combinatorial optimization: Graph partitioning and clustering [Organizer: Renato Werneck] [p. 171] Renato Werneck: Exact combinatorial branch-and-bound for graph bisection	Henning Meyerhenke: Current trends in graph clustering	H 3021
Complementarity and variational inequalities: Advances in the theory of complementarity and related problems II [p. 171] Maria Lignola: Mathematical programs with quasi-variational inequality constraints Fabio Raciti: On generalized Nash equilibrium problems: The Lagrange multipliers approach	Joachim Gwinner: On linear differential variational inequalities	MA 313
Conic programming: Semidefinite programming and geometric representations of graphs [Organizer: Monique Laurent and Christoph Helmberg] [p. 171] Susanna Reiss: Optimizing extremal eigenvalues of the weighted Laplacian of a graph Marcel de Carli Silva: Optimization problems over unit-distance representations of graphs	Antonios Varvitsiotis: Two new graph parameters related to semidefinite programming with a rank constraint	H 2036
Conic programming: Conic and convex programming in statistics and signal processing III [Organizer: Venkat Chandrasekaran] [p. 172] Deanna Needell: Randomized projection algorithms for overdetermined linear systems Stephen Wright: Packing ellipsoids (and chromosomes)	James Saunderson: Polynomial-sized semidefinite representations of derivative relaxations of spectral cones	H 2038
Constraint programming: Constraint solvers and implementations [Organizer: Narendra Jussien] [p. 172] Christian Schulte: Gecode: An open constraint solving library	Charles Prud'homme: A DSL for programming propagation engine	H 3003A
Derivative-free and simulation-based optimization: Derivative-free applications and parallelization [p. 172] Aurea Martinez: Design of river fishways: A derivative-free optimization perspective A. Ismael Vaz: Vibration-based structural health monitoring based on a derivative-free global optimization approach	Per-Magnus Olsson: Parallelization of algorithms for derivative-free optimization	H 3503
Finance and economics: Optimization methodologies in computational finance [Organizer: Wei Xu] [p. 173] Cristina Fulga: Higher moments and conditional value at risk optimization Wei Xu: A new sampling strategy willow tree method with application to path-dependent option pricing	Asaf Shupo: Optimal promotion rate in a cash campaign	H 3027
Game theory: Polynomial-time algorithms for mechanism design [Organizer: Berthold Vöcking] [p. 173] Piotr Knysta: Combinatorial auctions with verification for gold Gergely Csapo: The private provision of a public good: Digging for gold	Angelina Vidali: Scheduling, auctions and truthfulness	MA 005
Game theory: Analysis of auction mechanisms [Organizer: Vangelis Markakis] [p. 174] Renato Paes Leme: Polyhedral clinching auctions and the AdWords polytope Ioannis Caragiannis: Welfare and revenue guarantees in sponsored search auctions	Vasilis Syrgkanis: Efficiency in sequential auctions	MA 043
Global optimization: Global optimization methods and applications [Organizer: Sergiy Butenko] [p. 174] Panos Pardalos: Global optimality conditions in non-convex optimization Erick Moreno-Centeno: Solving combinatorial optimization problems as implicit hitting set problems	Austin Buchanan: Maximum clique problem on very large scale sparse networks	H 2053
Implementations and software: Exact MIP/LP solvers [Organizer: Daniel Steffy] [p. 174] Sebastian Hoffmann: Integration of an LP solver into interval constraint propagation Kati Wolter: An exact rational mixed-integer programming solver	Ojas Parekh: Computing certificates for integer programs	H 0110
Implementations and software: Software for PDE-constrained optimization [Organizer: Denis Ridzal] [p. 175] Joseph Young: Software abstractions for matrix-free PDE optimization with cone constraints Andreas Potschka: MUSCOP: A multiple shooting code for time-periodic parabolic PDE constrained optimization	Drosos Kourounis: Gradient-based optimization using adjoint methods for optimization of compositional flow in porous media	H 1058
Integer and mixed-integer programming: Scheduling II [p. 175] Karin Thörnblad: A time-indexed formulation of a flexible job shop problem including preventive maintenance and availability of fixtures Adam Wojciechowski: Opportunistic replacement scheduling with interval costs	Mahmut Gokce: Scheduling for disassembly systems	H 2013
Integer and mixed-integer programming: Polyhedral theory [Organizer: Quentin Louveaux] [p. 175] Carla Michini: How tight is the corner relaxation? Insights gained from the stable set problem Laurent Poirrier: The strength of multi-row models	Mahdi Doostmohammadi: Valid inequalities for the single arc design problem with set-ups	H 2032
Integer and mixed-integer programming: Lattices and integer programming [Organizer: Karen Aardal] [p. 176] Karen Aardal: The structure of LLL-reduced kernel lattice bases: Background and outline of the main result Frederik von Heymann: The structure of LLL-reduced kernel lattice bases: Theoretical details	Andrea Lodi: On cutting planes and lattice reformulations	H 2033

Life sciences and healthcare: (Next generation) sequences (Organizers: Gunnar Klau and Alexander Schönhuth) [p. 176] Stefan Canzar: Transcriptome reconstruction using delayed column generation	Susanne Pape: Computational complexity of the multiple sequence alignment problem	MA 376
Logistics, traffic, and transportation: TomTom routing and traffic research: Data, models and algorithms (Organizer: Heiko Schilling) Heiko Schilling: TomTom Navigation – How mathematics help getting through traffic faster	[p. 176] Arne Kesting: The dynamics of traffic jams – How data and models help to understand the principles behind	H 0104
Logistics, traffic, and transportation: Math programming in supply chain applications (Organizer: Pavithra Harsha) [p. 177] Paat Rusmevichientong: Robust assortment optimization	Pavithra Harsha: Demand-response in the electricity smart grid: A data-driven pricing and inventory optimization approach	H 0106
Logistics, traffic, and transportation: New algorithms for new pricing models (Organizer: Hamid Nazerzadeh) [p. 177] Luis Briceño-Arias: Optimal continuous pricing with strategic consumers	Azaraksh Malekian: Bayesian optimal auctions via multi- to single-agent reduction	H 0111
Mixed-integer nonlinear programming: Structured MINLP and applications (Organizer: Noam Goldberg) [p. 177] Toni Lastusilta: Chromatographic separation using GAMS extrinsic functions	Susan Margulies: Hilbert's Nullstellensatz and the partition problem: An infeasibility algorithm via the partition matrix and the partition polynomial	MA 041
Mixed-integer nonlinear programming: Topics in mixed-integer nonlinear programming II [p. 178] Melania Calinescu: Optimal resource allocation in survey designs	[p. 178] Michael Engelhart: A new test-scenario for analysis and training of human decision making with a tailored decomposition approach	MA 042
Multi-objective optimization: Nonlinear multiobjective optimization [p. 178] Shashi Mishra: On constraint qualifications in multiobjective optimization problems with vanishing constraints	Luis Lucambio Perez: A modified subgradient algorithm for solving K -convex inequalities	H 1029
Nonlinear programming: Regularization techniques in optimization II (Organizer: Jacek Gondzio) [p. 178] Stefania Bellavia: Regularized Euclidean residual algorithm for nonlinear least-squares with strong local convergence properties	Serge Gratton: Preconditioning inverse problems using duality	H 0107
Nonlinear programming: Applications of optimization I [p. 179] Makoto Yamashita: An approach based on shortest path and connectivity consistency for sensor network localization problems	Marc Steinbach: Estimating material parameters by x-ray diffraction	H 0112
Nonsmooth optimization: Applications of nonsmooth optimization [p. 179] Ann-Brith Strömberg: Lagrangian optimization for inconsistent linear programs	Amirhossein Sadoghi: Piecewise monotonic regression algorithm for problems comprising seasonal and monotonic trends	H 1012
Optimization in energy systems: Robust aspects of optimization in energy management (Organizer: Wim van Ackooij) [p. 179] Wim van Ackooij: Decomposition methods for unit-commitment with coupling joint chance constraints	Raimund Kovacevic: A process distance approach for scenario tree generation with applications to energy models	MA 549
Optimization in energy systems: Stochastic optimization applied to power systems (Organizer: Sara Lumbreras) [p. 180] Sara Lumbreras: Efficient incorporation of contingency scenarios to stochastic optimization. Application to power systems.	Francisco Munoz: Using decomposition methods for wide-area transmission planning to accommodate renewables: A multi-stage stochastic approach	MA 550
PDE-constrained optimization and multi-level/multi-grid methods: Optimization applications in industry IV (Organizer: Dietmar Hömberg) [p. 180] Hans Josef Pesch: Direct versus indirect solution methods in real-life applications: Load changes of fuel cells	Jean-Antoine Desideri: Multiple gradient descent algorithm (MGDA) for multi-objective optimization with application to compressible aerodynamics	MA 415

<p>Robust optimization: Applications of robust optimization IV [p. 180] Jorge Vera: Improving consistency of tactical and operational planning using robust optimization</p>	<p>Florian Bruns: Robust load planning of trains in intermodal transportation</p>	<p>Pierre-Louis Poirion: Robust optimal sizing of a hybrid energy stand-alone system</p>	MA 004
<p>Sparse optimization and compressed sensing: Efficient first-order methods for sparse optimization and its applications [Organizer: Shiqian Ma] [p. 181] Shiqian Ma: An alternating direction method for latent variable Gaussian graphical model selection</p>	<p>Zhaosong Lu: Sparse approximation via penalty decomposition methods</p>	<p>Donald Goldfarb: An accelerated linearized Bregman method</p>	H 1028
<p>Stochastic optimization: Scenario generation in stochastic optimization [Organizer: David Papp] [p. 181] David Papp: Generating moment matching scenarios using optimization techniques</p>	<p>Teemu Pennanen: Tractability of stochastic programs</p>	<p>Jitmitra Desai: A mathematical programming framework for decision tree analysis</p>	MA 141
<p>Stochastic optimization: Large-scale stochastic programming [Organizer: Mihai Anitescu] [p. 182] Andreas Grothey: Multiple-tree interior point method for stochastic programming</p>	<p>Miles Lubin: Parallel and distributed solution methods for two-stage stochastic (M)ILPs</p>	<p>Werner Roemisch: Are quasi-Monte Carlo methods efficient for two-stage stochastic programs?</p>	MA 144
<p>Telecommunications and networks: Length bounded trees [Organizer: Markus Leitner] [p. 182] Ivana Ljubic: Layered graph models for hop constrained trees with multiple roots</p>	<p>Markus Leitner: New models for the diameter constrained steiner tree problem</p>	<p>Andreas Bley: Capacitated facility location with length bounded trees</p>	H 3002
<p>Variational analysis: Structural properties in variational analysis [Organizer: Stephen Robinson] [p. 182] Boris Mordukhovich: Second-Order variational analysis and stability in optimization</p>	<p>Adrian Lewis: Active sets and nonsmooth geometry</p>	<p>Shu Lu: Confidence regions and confidence intervals for stochastic variational inequalities</p>	H 2035
<p>Variational analysis: Equilibrium problems: Formulations and methodologies [Organizer: Patrizia Daniele] [p. 183] Patrizia Daniele: General financial models: Methodologies and suggestions for the recovery</p>	<p>Giovanni Crespi: Minty variational principle in set optimization</p>	<p>Tina Wakolbinger: A variational inequality formulation of economic network equilibrium models with nonlinear constraints</p>	H 2051
Wednesday 15:15–16:45			
<p>Approximation and online algorithms: Randomized rounding algorithms in mathematical programming [Organizer: Maxim Sviridenko] [p. 183] Viswanath Nagarajan: Thresholded covering algorithms for robust and max-min optimization</p>	<p>Barna Saha: The constructive aspects of the Lovász Local Lemma: finding needles in a haystack</p>	<p>Aravind Srinivasan: Dependent rounding and its applications</p>	H 3010
<p>Combinatorial optimization: Knapsack and bin packing [p. 183] Alantha Newman: A counterexample to Beck's three permutations conjecture</p>	<p>Paolo Detti: The bounded sequential multiple knapsack problem</p>	<p>Joachim Schauer: Knapsack problems with disjunctive constraints</p>	H 3004
<p>Combinatorial optimization: Graph coloring [p. 184] Noriyoshi Sukegawa: Lagrangian relaxation and pegging test for clique partitioning problems</p>	<p>Jakub Marecek: Semidefinite programming relaxations in timetabling and matrix-free implementations of augmented Lagrangian methods for solving them</p>	<p>H 3005</p>	
<p>Combinatorial optimization: Competitive and multi-objective facility location [p. 184] Vladimir Beresnev: Algorithms for discrete competitive facility location problem</p>	<p>Yury Kochetov: A local search algorithm for the $(r p)$-centroid problem on the plane</p>	<p>Marta Pascoal: Path based method for multicriteria metro location</p>	H 3008
<p>Combinatorial optimization: Heuristics III [p. 184] Polina Kononova: Local search heuristic for the buffer-constrained two-stage multimedia scheduling problem</p>	<p>Beysanur Cayir: A genetic algorithm for truck to door assignment in warehouses</p>	<p>H 3012</p>	
<p>Combinatorial optimization: Polyhedra in combinatorial optimization [p. 185] Shungo Koichi: A note on ternary semimodular polyhedra</p>	<p>Aleksandr Maksimenko: The common face of some 0/1 polytopes with NP-complete nonadjacency relations</p>	<p>Shanfei Li: The polyhedral relationship between the capacitated facility location polytope and its knapsack and single-node flow relaxations</p>	H 3013

<p>Combinatorial optimization: Routing in road networks [Organizer: Andrew Goldberg] [p. 185] Peter Sanders: Advance route planning using contraction hierarchies</p>	<p>Daniel Delling: Realistic route planning in road networks</p>	<p>H 3021</p>
<p>Complementarity and variational inequalities: Applications of complementarity [p. 185] Jong-Shi Pang: On differential linear-quadratic Nash games with mixed state-control constraints</p>	<p>Wen Chen: A power-penalty method for fractional Black-Scholes equations governing American option pricing</p>	<p>MA 313</p>
<p>Conic programming: First-derivative methods in convex optimization [p. 186] Yoel Drori: Performance of first-order methods for smooth convex minimization: A novel approach</p>	<p>Sahar Karimi: CGSO for convex problems with polyhedral constraints</p>	<p>H 2036</p>
<p>Conic programming: Conic and convex programming in statistics and signal processing IV [Organizer: Parikshit Shah] [p. 186] Defeng Sun: Finding the nearest correlation matrix of exact low rank via convex optimization</p>	<p>Maryam Fazel: Algorithms for Hankel matrix rank minimization for system identification and realization</p>	<p>H 2038</p>
<p>Constraint programming: Computational sustainability [Organizer: Alan Holland] [p. 186] Alan Holland: Optimising the economic efficiency of monetary incentives for renewable energy investment</p>	<p>Marco Gavaneli: Simulation and optimization for sustainable policy-making</p>	<p>H 3003A</p>
<p>Derivative-free and simulation-based optimization: Stochastic zero-order methods [Organizers: Stefan Wild and Luis Nunes Vicente] [p. 187] Joao Lauro Faco: A continuous GRASP for global optimization with general linear constraints</p>	<p>Anne Auger: Convergence of adaptive evolution strategies on monotonic C^2-composite and scale-invariant functions</p>	<p>H 3503</p>
<p>Finance and economics: Management of portfolios and liabilities [Organizers: Dan Iancu and Nikos Trichakis] [p. 187] Alberto Martín-Utrera: Size matters: Calibrating shrinkage estimators for portfolio optimization</p>	<p>Pedro Júdice: Long-term bank balance sheet management: Estimation and simulation of risk-factors</p>	<p>H 3027</p>
<p>Game theory: Network sharing and congestion [Organizer: Laurent Gourves] [p. 187] Alexandre Blogowski: Access network sharing between two telecommunication operators</p>	<p>Xavier Zeitoun: The complexity of approximate Nash equilibrium in congestion games with negative delays</p>	<p>MA 005</p>
<p>Game theory: Solving cooperative games [p. 188] Tri-Dung Nguyen: Finding solutions of large cooperative games</p>	<p>Kazutoshi Ando: Computation of the Shapley value of minimum cost spanning tree games: #P-hardness and polynomial cases</p>	<p>MA 043</p>
<p>Global optimization: Nonconvex optimization: Theory and algorithms [Organizer: Evrim Dalkiran] [p. 188] Evrim Dalkiran: RLT-POS: Reformulation-linearization technique-based optimization software for polynomial programming problems</p>	<p>Spencer Schaber: Convergence order of relaxations for global optimization of nonlinear dynamic systems</p>	<p>H 2053</p>
<p>Implementations and software: Commercial mathematical programming solvers I [Organizer: Hans Mittelmann] [p. 189] Thorsten Koch: Any progress one year after MIPLIB 2010?</p>	<p>Tobias Achterberg: Cover probing for mixed integer programs</p>	<p>H 0110</p>
<p>Implementations and software: Software for large-scale optimization [Organizer: Denis Ridzal] [p. 189] Kevin Long: Sundance: High-level software for PDE-constrained optimization</p>	<p>Eric Phipps: Support embedded algorithms through template-based generic programming</p>	<p>H 1058</p>
<p>Integer and mixed-integer programming: Scheduling III [p. 189] Nelson Hein: Mathematical model of hierarchical production planning</p>	<p>Rüdiger Stephan: Smaller compact formulation for lot-sizing with constant batches</p>	<p>H 2013</p>
<p>Integer and mixed-integer programming: Branch-and-price I: Generic solvers [Organizer: Marco Lübbecke] [p. 189] Marco Lübbecke: A generic branch-price-and-cut solver</p>	<p>Matthew Galati: The new decomposition solver in SAS/OR</p>	<p>H 2032</p>

<p>Integer and mixed-integer programming: Some bridges between algebra and integer programming [Organizer: Justo Puerto] [p. 190] Víctor Blanco: Applications of discrete optimization to numerical semigroups José-María Ucha: Algebraic tools for nonlinear integer programming problems 1: Getting started.</p>	<p>[Organizer: Edwin Romeijn] [p. 190] Albin Fredriksson: A characterization of robust radiation therapy optimization methods</p>	<p>Mania Isabel Hartillo: Algebraic tools for nonlinear integer programming problems 2: Applications</p>	<p>H 2033</p>
<p>Life sciences and healthcare: Radiation therapy treatment planning [Organizer: Edwin Romeijn] [p. 190] Troy Long: Beam orientation optimization in radiation therapy treatment planning</p>	<p>[p. 190] Elmar Swarat: Modeling and solving a toll enforcement problem</p>	<p>Marina Epelman: A column generation-based algorithm for Volumetric Modulated Arc Therapy (VMAT) treatment plan optimization</p>	<p>MA 376</p>
<p>Logistics, traffic, and transportation: Vehicle and crew planning [p. 190] Gary Froyland: Robust airline schedule planning, aircraft routing and crew pairing: An integrated scenario-based approach</p>	<p>[p. 191] Weng Hei Tou: A dial-a-ride problem for public transport using electric vehicles</p>	<p>Güvenc Sahin: Tactical and strategic crew planning problems in railways</p>	<p>H 0106</p>
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<p>Mixed-integer nonlinear programming: Topics in mixed-integer nonlinear programming III [p. 192] Duan Li: MIQP solvers for quadratic programs with cardinality and minimum threshold constraints: A semidefinite program approach</p>	<p>[Organizer: Andreas Löhne] [p. 192] Andreas Löhne: BENSOLVE – a solver for multi-objective linear programs</p>	<p>Geeta Kumari: Symmetric duality for multiobjective second-order fractional programs</p>	<p>MA 042</p>
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<p>Nonlinear programming: Line-search strategies [Organizer: José Mario Martínez] [p. 192] Ernesto G. Birgin: Spectral-projected gradients: Reviewing ten years of applications</p>	<p>[p. 193] Alina Fedosova: Modeling of transboundary pollutant displacement for groups of emission sources</p>	<p>Natasa Krejic: Nonmonotone line search methods with variable sample sizes</p>	<p>H 0107</p>
<p>Nonlinear programming: Applications of optimization II [p. 193] Thea Göllner: Geometry optimization of branched sheet metal products</p>	<p>[p. 193] Pando Georgiev and Julian Revalski [p. 193] Pando Georgiev: Global optimality conditions of first order for non-smooth functions in a Banach space</p>	<p>Alina Fedosova: Modeling of transboundary pollutant displacement for groups of emission sources</p>	<p>H 0112</p>
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<p>Optimization in energy systems: Stochastic programming in energy [Organizer: Asgeir Tomasgard] [p. 193] Gerardo Perez Valdes: Parallel computational implementation of a branch and fix coordination algorithm</p>	<p>[p. 193] Daniel Ralph and Andreas Ehrenmann [p. 193] Gauthier de Maere: Modelling market liquidity in restructured power systems by stochastic Nash and generalized Nash equilibrium</p>	<p>Andreas Ehrenmann: Risk adjusted discounting</p>	<p>MA 549</p>
<p>Optimization in energy systems: Stochastic equilibria in energy markets I [Organizers: Daniel Ralph and Andreas Ehrenmann] [p. 193] Golbon Zakeri: Models for large consumer peak shaving and the impact on line pricing</p>	<p>[p. 194] Dietmar Hömberg [p. 194] Stephania Hokenmaier: Optimization with discontinuities and approximations in process engineering</p>	<p>Stephanie Hokenmaier: Optimization with discontinuities and approximations in process engineering</p>	<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Optimization applications in industry V [Organizer: Dietmar Hömberg] [p. 194] Arnd Roesch: Optimal control of a chemotaxis problem</p>	<p>[p. 194] Adrian Sichau: Shape optimization under uncertainty employing a second order approximation for the robust counterpart</p>	<p>Adrian Sichau: Shape optimization under uncertainty employing a second order approximation for the robust counterpart</p>	<p>MA 415</p>
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Sparse optimization and compressed sensing: Structured models in sparse optimization (Organizer: John Duchi) [p. 194] Rodolphe Jenatton: Proximal methods for hierarchical sparse coding and structured sparsity	John Duchi: Adaptive subgradient methods for stochastic optimization and online learning	H 1028
Stochastic optimization: Algorithms and applications for stochastic programming (Organizer: Yongpei Guan) [p. 195] ZhiLi Zhou: A network based model for traffic sensor placement with implications on congestion observation	Guzin Bayraksan: A sequential bounding method for a class of two-stage stochastic programs	MA 141
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Telecommunications and networks: Local access networks (Organizer: Stefan Gollowitz) [p. 196] Stefan Gollowitz: Capacitated network design with facility location	Ashwin Arulselman: An incremental algorithm for the facility location problem	H 3002
Variational analysis: Nonsmooth analysis with applications in engineering (Organizer: Radek Cibulka) [p. 196] Alfredo Iusem: Th effect of calmness on the solution set of nonlinear equations	Radek Cibulka: Quantitative stability of a generalized equation: Application to non-regular electrical circuits	H 2035
Variational analysis: Some stability aspects in optimization theory (Organizers: Abderrahim Hantoute and Rafael Correa) [p. 196] Abderrahim Hantoute: On convex relaxation of optimization problems	Vladimir Shikhman: Implicit vs. inverse function theorem in nonsmooth analysis	H 2051
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Approximation and online algorithms: Approximation algorithms [p. 197] David Williamson: A dual-fitting $\frac{3}{2}$ -approximation algorithm for some minimum-cost graph problems	Naonori Kakimura: Computing knapsack solutions with cardinality robustness	H 3010
Combinatorial optimization: Optimization and enumeration (Organizers: Jaroslav Neseřil and Martin Loeb) [p. 197] Patrice Ossona de Mendez: Large structured induced subgraphs with close homomorphism statistics	Amin Coja-Oghlan: Catching the k-NAESAT threshold	H 3004
Combinatorial optimization: Robust network design (Organizer: Michael Juenger) [p. 197] Manuel Kutschka: Robust metric inequalities for network design under demand uncertainty	Laura Sanità: Steiner tree approximation via iterative randomized rounding	H 3005
Combinatorial optimization: Resource placement in networks (Organizer: David Johnson) [p. 197] David Johnson: Disjoint-path facility location: theory and practice	Adelaide Cerveira: A two-stage branch and bound algorithm to solve truss topology design problems	H 3008
Combinatorial optimization: Exact algorithms for hard problems [p. 198] Réal Carboneau: Globally optimal clusterwise regression by branch and bound optimization with heuristics, sequencing and ending subset	Torsten Klug: An approach for solving the freight train routing problem	H 3012
Combinatorial optimization: Combinatorial optimization in railways II (Organizer: Ralf Borndörfer) [p. 198] Ronny Hansmann: Minimal shunting operations for freight train composition	Kai Plociennik: A probabilistic PTAS for shortest common superstring	H 3013
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<p>Complementarity and variational inequalities: Bilevel programs and MPECs [Organizer: Jane Ye] [p. 199] Chao Ding: First order optimality conditions for mathematical programs with semidefinite cone complementarity constraints</p>	<p>Jane Ye: On solving bilevel programs with a nonconvex lower level program</p>	<p>MA 313</p>
<p>Conic programming: Linear programming: theory and algorithms [p. 199] Andre Tits: The power of constraint reduction in interior-point methods</p>	<p>Barbara Abdessamad: Strict quasi-concavity and the differential barrier property of gauges in linear programming</p>	<p>H 2036</p>
<p>Conic programming: New results in copositive and semidefinite optimization [Organizer: Mirjam Dür] [p. 200] Luuk Gijben: Scaling relationship between the copositive cone and Parrilo's first level approximation</p>	<p>Faizan Ahmed: On connections between copositive programming and semi-infinite programming</p>	<p>H 2038</p>
<p>Constraint programming: Instance-specific tuning, selection, and scheduling of solvers [Organizer: Meinolf Sellmann] [p. 200] Meinolf Sellmann: Solver portfolios</p>	<p>Lin Xu: Evaluating component solver contributions to portfolio-based algorithm selectors</p>	<p>H 3003A</p>
<p>Finance and economics: Risk management in financial markets [Organizers: Nikos Trichakis and Dan Iancu] [p. 200] Gerry Tsoukalas: Dynamic portfolio execution</p>	<p>Vishal Gupta: A data-driven approach to risk preferences</p>	<p>H 3027</p>
<p>Game theory: Mechanisms for resource allocation problems [Organizer: Giorgos Christodoulou] [p. 201] Carmine Ventre: Using lotteries to approximate the optimal revenue</p>	<p>Annamaria Kovacs: Characterizing anonymous scheduling mechanisms for two tasks</p>	<p>MA 005</p>
<p>Game theory: Mean-field approaches to large scale dynamic auctions and mechanisms [Organizers: Gabriel Weintraub and Santiago Balseiro] [p. 201] Krishnamurthy Iyer: Mean field equilibria of dynamic auctions with learning</p>	<p>Alexandre Proutiere: Optimal bidding strategies and equilibria in repeated auctions with budget constraints</p>	<p>MA 043</p>
<p>Global optimization: Advances in global optimization I [p. 201] Dmytro Leshchenko: Optimal deceleration of an asymmetric gyrostator in a resistive medium</p>	<p>Pál Burai: Necessary and sufficient condition on global optimality without convexity and second order differentiability</p>	<p>H 2053</p>
<p>Implementations and software: Commercial mathematical programming solvers II [Organizer: Hans Mittelmann] [p. 202] Hans Mittelmann: Selected benchmarks in continuous and discrete optimization</p>	<p>Robert Bixby: Presolve for linear and mixed-integer programming</p>	<p>H 0110</p>
<p>Implementations and software: Modeling languages and software I [Organizer: Robert Fourer] [p. 202] John Sirolla: Modeling and optimizing block-composable mathematical programs in Pyomo</p>	<p>Robert Fourer: Strategies for using algebraic modeling languages to formulate second-order cone programs</p>	<p>H 1058</p>
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<p>Integer and mixed-integer programming: Branch-and-price II: Column and row generation [Organizer: Marco Lübbecke] [p. 203] Pedro Munari: Using interior point methods in branch-price-and-cut framework</p>	<p>Ruslan Sadykov: Column generation for extended formulations</p>	<p>H 2032</p>
<p>Integer and mixed-integer programming: New developments in integer programming [Organizer: Andreas S. Schulz] [p. 203] Daniel Dadush: Convex minimization over the integers</p>	<p>Juliane Dunkel: A refined Gomory-Chvátal closure for polytopes in the unit cube</p>	<p>H 2033</p>
<p>Life sciences and healthcare: Life sciences and healthcare "à la Clermontoise" [Organizer: Annegret Wagler] [p. 203] Vincent Barra: Assessing functional brain connectivity changes in cognitive aging using RS-fMRI and graph theory</p>	<p>Romain Pogorelcnik: Clique separator decomposition and applications to biological data</p>	<p>MA 376</p>
<p>Logistics, traffic, and transportation: Analysis of decentralized network systems [Organizers: Ozlem Ergun and Luyi Gui] [p. 204] Daniela Saban: The competitive facility location game: Equilibria and relations to the 1-median problem</p>	<p>Douglas Fearing: Managing air traffic disruptions through strategic prioritization</p>	<p>H 0106</p>

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Mixed-integer nonlinear programming: MINLP theory and algorithms (Organizer: Giacomo Nannicini) [p. 205] Emiliano Traversi: Separable underestimators for quadratic combinatorial optimization	Stefano Coniglio: Spatial branch-and-bound for nonconvex Euclidean norm constrained mathematical programs	MA 042
Multi-objective optimization: Vector optimization (Organizers: César Gutiérrez and Vicente Novo) [p. 205] Marta Beatriz Hernández-Jiménez: Characterization of efficient solutions for non-regular multiobjective problems with inequality-type constraints	Fabián Flores-Bazán: Efficiency and ordering variational principles	H 1029
Nonlinear programming: Linear algebra for optimization (Organizer: Dominique Orban) [p. 205] Martin Stoll: Preconditioning for time-dependent PDE-constrained optimization problems	Dominique Orban: Spectral analysis of matrices arising in regularized interior-point methods	H 0107
Nonlinear programming: Convex nonlinear optimization I [p. 205] Stefan Stefanov: Convex separable minimization with box constraints	Ganesh Peruma: A decomposition technique for convex optimization problems	H 0112
Nonsmooth optimization: Nonsmooth optimization theory [p. 206] Anna-Laura Wickström: Generalized derivatives of the projection onto the cone of positive semidefinite matrices	Waltraud Huyer: Minimizing functions containing absolute values of variables	H 1012
Optimization in energy systems: Capacity of gas transport networks (Organizer: Thorsten Koch) [p. 206] Christine Hayn: Optimal allocation of capacities in gas networks	Benjamin Hiller: An automated method for the booking validation problem	MA 549
Optimization in energy systems: Gas and electricity networks (Organizer: Alexander Martin) [p. 206] Robert Schwarz: Gas network design with integrated optimization of topology and dimensioning	Ken McKinnon: An MINLP approach to islanding electricity networks	MA 550
PDE-constrained optimization and multi-level/multi-grid methods: PDE optimization in medicine I (Organizer: Anton Schiela) [p. 207] Luis A. Fernandez: Optimizing a chemotherapy model for brain tumors by using PDE	Lars Lubkoll: Optimal control in implant shape design	H 0111
PDE-constrained optimization and multi-level/multi-grid methods: Optimization applications in industry VI (Organizer: Dietmar Hömberg) [p. 207] Ekaterina Kostina: Optimization methods for nonlinear model predictive control of non-stationary partial differential equations	Dietmar Hömberg: Optimal control of multiphase steel production	MA 415
Robust optimization: Robust optimization, estimation and machine learning (Organizer: Aharon Ben-Tal) [p. 207] Shimrit Shtern: A robust optimization approach for tracking under bounded uncertainty	Chiranjib Bhattacharyya: Making SVM Classifiers robust to uncertainty in kernel matrices	MA 004
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Stochastic optimization: High dimensional statistics: Techniques from stochastic and robust optimization (Organizer: Constantine Caramanis) [p. 208] Philippe Rigollet: Deviation optimal model selection using greedy algorithms	Sujay Sanghavi: Learning the graph of network cascades	MA 141
Stochastic optimization: Decomposition methods for multistage stochastic programs (Organizer: Vincent Guigues) [p. 208] Vincent Guigues: Sampling-based decomposition methods for multistage stochastic programs based on extended polyhedral risk measures	Suvrajeet Sen: Multi-stage stochastic decomposition	MA 144

<p>Telecommunications and networks: Networks in production, logistics and transport [p. 209] Sabine Büttner: Online network routing amongst unknown obstacles</p>	<p>Marco Bender: Online delay management: Beyond competitive analysis</p>	<p>H 3002</p>
<p>Telecommunications and networks: Allocation problems [p. 209] Hasan Turan: Volume discount pricing policy for capacity acquisition and task allocation models in telecommunication with fuzzy QoS Constraints</p>	<p>Deepak Garg: Heuristic mathematical models for solving dynamic task assignment problem in distributed real time systems</p>	<p>H 3503</p>
<p>Variational analysis: Structure and stability of optimization problems [p. 209] Jan-J Ruckmann: Max-type objective functions: A smoothing procedure and strongly stable stationary points</p>	<p>Peter Fusek: On metric regularity of the Kojima function in nonlinear semidefinite programming</p>	<p>H 2035</p>
<p>Variational analysis: Optimization methods for nonsmooth inverse problems in PDEs [Organizers: Akhtar Khan and Christian Clason] [p. 210] Barbara Kaltenbacher: Iterative regularization of parameter identification in PDEs in a Banach space framework</p>	<p>Christian Clason: Inverse problems for PDEs with uniform noise</p>	<p>H 2051</p>
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<p>Approximation and online algorithms: Scheduling, packing and covering [Organizer: Nicole Megow] [p. 210] Wiebke Höhn: On the performance of Smith's rule in single-machine scheduling with nonlinear cost</p>	<p>Alexander Souza: Approximation algorithms for generalized and variable-sized bin covering</p>	<p>H 3010</p>
<p>Combinatorial optimization: Cycles in graphs [p. 210] Eva-Maria Sprengel: An optimal cycle packing for generalized Petersen graphs $P(n, k)$ with k even</p>	<p>Lamia Aoudia: 4-cycle polytope on a graph</p>	<p>H 3004</p>
<p>Combinatorial optimization: Distance geometry and applications [Organizers: Antonio Mucherino and Nelson Maculan] [p. 211] Carlile Laver: A discrete approach for solving distance geometry problems related to protein structure</p>	<p>Deok-Soo Kim: Molecular distance geometry problem: A perspective from the Voronoi diagram</p>	<p>H 3005</p>
<p>Combinatorial optimization: Discrete structures and algorithms II [Organizer: Satoru Fujishige] [p. 211] Akiyoshi Shioura: Computing the convex closure of discrete convex functions</p>	<p>Britta Peis: Resource buying games</p>	<p>H 3008</p>
<p>Combinatorial optimization: Nonlinear combinatorial optimization [p. 211] Laura Klein: Separation algorithms for quadratic combinatorial optimization problems</p>	<p>Marta Vidal: A new proposal for a lower bound in a generalized quadratic assignment problem applied to the zoning problem</p>	<p>H 3012</p>
<p>Combinatorial optimization: Inverse problems [p. 212] Natalia Shakhlevich: On general methodology for solving inverse scheduling problems</p>	<p>Peter Gritzmann: On some discrete inverse problems: Combinatorial optimization in discrete and refraction tomography</p>	<p>H 3013</p>
<p>Combinatorial optimization: Combinatorial optimization under uncertainty [Organizer: Bo Chen] [p. 212] Xiuli Chao: Dynamic pricing decision for a monopoly with strategic customers and price adjustment</p>	<p>Zhichao Zheng: Least square regret in stochastic discrete optimization</p>	<p>H 3021</p>
<p>Complementarity and variational inequalities: Iterative methods for variational inequalities [Organizers: Igor Konnov and Vyacheslav Kalashnikov] [p. 213] Igor Konnov: Extended systems of primal-dual variational inequalities</p>	<p>Vyacheslav Kalashnikov: Finding a conjectural variations equilibrium in a financial model by solving a variational inequality problem</p>	<p>MA 313</p>
<p>Conic programming: Conic relaxation approaches for scheduling and selection problems [p. 213] Karthik Natarajan: On theoretical and empirical aspects of marginal distribution choice models</p>	<p>Yuan Yuan: Integrated ship plan of strip coil consolidation and stowage</p>	<p>H 2036</p>

<p>Conic programming: Interior-point methods for conic programming [p. 213] Chek Beng Chua: Weighted analytic centers for convex conic programming</p>	<p>Bo Kyung Choi: New large-update primal-dual interior-point algorithms for symmetric optimization problems</p>	H 2038
<p>Derivative-free and simulation-based optimization: Addressing noise in derivative-free optimization [Organizers: Luis Nunes Vicente and Stefan Wild] [p. 214] Stefan Wild: Computational noise in simulation-based optimization</p>	<p>Stephen Billups: Managing the trust region and sample set for regression model based methods for optimizing noisy functions without derivatives</p>	H 3003A
<p>Finance and economics: Optimization and economic applications [Organizer: Kenneth Judd] [p. 214] Sebastián Lozano: Choosing the best partner for a horizontal cooperation</p>	<p>Nasser-Eddine Tatar: Asymptotic stability for the endogenous Solow model with discrete and distributed delays</p>	H 3027
<p>Game theory: Efficiency and optimization in games [Organizer: Ioannis Caragiannis] [p. 214] Francesco Pasquale: Logit dynamics: Expected social welfare, mixing time, and metastability</p>	<p>Giorgos Christodoulou: Coordination mechanisms for selfish routing games</p>	MA 005
<p>Game theory: Game theory in supply chain management [p. 215] Tiru Arthanari: Game theory and supply chain management: A survey</p>	<p>Ravindran Gomadam: Centrality in social networks</p>	MA 043
<p>Global optimization: Advances in global optimization II [p. 215] Andrei Orlov: On an approach to special nonlinear bilevel problems</p>	<p>Alireza Doagooei: Global optimization on the difference of sub-topical functions</p>	H 2053
<p>Implementations and software: Modeling languages and software II [Organizer: Robert Fourer] [p. 215] Ronald Hochreiter: Optimization modeling using R</p>	<p>Leo Lopes: Network optimization and beyond in SAS/OR® Software</p>	H 1058
<p>Integer and mixed-integer programming: Network analysis [p. 216] Xavier Molinero: Variations in strict separating systems representing a linearly separable function</p>	<p>Stefan Wiesberg: Computing role structures in networks</p>	H 2013
<p>Integer and mixed-integer programming: Branch-and-price III: New techniques [Organizer: Marco Lübbecke] [p. 216] Martin Bergner: Packing cuts with column generation</p>	<p>Jacques Desrosiers: Row-reduced column generation for highly degenerate master problems</p>	H 2032
<p>Integer and mixed-integer programming: Strong relaxations for stable set and lot sizing [Organizer: Jeff Linderoth] [p. 216] Monia Giandomenico: An ellipsoidal relaxation for the stable set problem</p>	<p>Laurence Wolsey: The one warehouse multiple retailer problem with start-ups and constant capacities</p>	H 2033
<p>Life sciences and healthcare: Scheduling, assignment and matching in healthcare [p. 217] Andrea Trautsumwieser: A branch-and-price approach for solving medium term home health care planning problems</p>	<p>Sarah Kirchner: Appointment scheduling in a hospital environment</p>	MA 376
<p>Logistics, traffic, and transportation: Traffic assignment [p. 217] Olga Perederieieva: Solving the time surplus maximisation bi-objective user equilibrium model of traffic assignment</p>	<p>Suh-Wen Chiou: Modeling the performance reliability in an area traffic control road network under uncertainty</p>	H 0106
<p>Logistics, traffic, and transportation: Synchronization and collision avoidance [p. 218] F. Javier Martin-Campo: On solving the aircraft collision avoidance problem for the ATM by horizontal maneuvers. A ranked multiobjective MINLO problem</p>	<p>Torsten Gellert: Scheduling multiple cranes on a shared pathway</p>	MA 042
<p>Mixed-integer nonlinear programming: Convex approaches for quadratic integer programs [Organizers: Adam Letchford and Samuel Burer] [p. 218] Adam Letchford: A new separation algorithm for the Boolean quadric and cut polytopes</p>	<p>John Mitchell: Quadratic programs with complementarity constraints</p>	MA 041

<p>Multi-objective optimization: Vector optimization II [p. 218] Xuexiang Huang: Calmness and exact penalization for constrained vector set-valued optimization problems</p>	<p>Stefan Ruzika: "Vectorization" as a principle in optimization!?</p>	<p>H 1029</p>
<p>Nonlinear programming: Algorithms and applications I [Organizer: Ya-xiang Yuan] [p. 218] Coralia Cartis: On the evaluation complexity of constrained nonlinear programming</p>	<p>Xiao Wang: An augmented Lagrangian trust region method for nonlinear programming</p>	<p>H 0107</p>
<p>Nonlinear programming: Interior-point methods for linear programming [p. 219] Aurelio Oliveira: Continued iteration and simple algorithms on interior point methods for linear programming</p>	<p>Luciana Casacio: New preconditioners for interior point methods in linear programming</p>	<p>H 0110</p>
<p>Nonlinear programming: Semidefinite and DC programming [p. 219] Ibraheem Aloyan: Zeros of quadratic interval polynomials</p>	<p>Stephane Gaubert: Policy iteration algorithm for zero-sum stochastic games with mean payoff</p>	<p>H 0112</p>
<p>Nonsmooth optimization: Policy iteration algorithms and some applications [Organizer: Hasnaa Zidani] [p. 219] Hasnaa Zidani: Some convergence results for the policy iterations algorithm.</p>	<p>Stephane Gaubert: Policy iteration algorithm for zero-sum stochastic games with mean payoff</p>	<p>H 1012</p>
<p>Optimization in energy systems: Optimization in the natural gas markets [Organizer: Guillaume Erbs] [p. 220] Guillaume Erbs: Application of stochastic dual dynamic programming to the analysis of natural gas markets</p>	<p>Asgeir Tomasgard: Multi-stage stochastic programming for natural gas infrastructure design</p>	<p>MA 549</p>
<p>Optimization in energy systems: Bilevel programming and housing retrofit [p. 220] Eugene Zak: Bilevel Programming for combinatorial auctions in electricity markets</p>	<p>Mark Jennings: Optimization of technology investments and capital management in an urban energy system housing retrofit project: Use of rolling horizons in a London borough study</p>	<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: PDE optimization in medicine II [Organizer: Anton Schiela] [p. 220] Martin Frank: Optimal radiotherapy treatment planning using minimum entropy models</p>	<p>Malik Kirchner: Large deformation diffeomorphic metric mapping using conforming adaptive finite elements</p>	<p>H 0111</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Theory and methods for PDE-constrained optimization problems with inequalities [Organizer: Michael Ulbrich] [p. 221] Francisco José Silva Alvarez: Characterization of quadratic growth for strong minima in the optimal control of semi-linear elliptic equations</p>	<p>Florian Kruse: An infeasible interior point method for optimal control problems with state constraints</p>	<p>MA 415</p>
<p>Robust optimization: Multistage robustness [Organizer: Ulf Lorenz] [p. 221] Jan Wolf: Accelerating nested Benders decomposition with game-tree search techniques to solve quantified linear programs</p>	<p>Marc Goerigk: A geometric approach to recovery robustness</p>	<p>MA 004</p>
<p>Sparse optimization and compressed sensing: Nonconvex sparse optimization [Organizer: Wotao Yin] [p. 221] Zaiwen Wen: Alternating direction augmented Lagrangian methods for a few nonconvex problems</p>	<p>Ming-Jun Lai: On the Schatten p-quasi-norm minimization for low rank matrix recovery</p>	<p>H 1028</p>
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<p>Telecommunications and networks: Network clustering [Organizer: Sergiy Butenko] [p. 222] Michael Ovelgonne: Ensemble learning for combinatorial optimization: Modularity maximization and beyond</p>	<p>Cong Sun: Low complexity interference alignment algorithms for desired signal power maximization problem of MIMO channels</p>	<p>H 3002</p>

Telecommunications and networks: Paths, trees and flows [p. 223] Alvaro Franco: A new linear time algorithm to construct dominator trees of reducible flow graphs	Elena Fernandez: A compact formulation for the optimum communication spanning tree problem	H 3503
Variational analysis: Stability of constraint systems [Organizer: René Henrion] [p. 223] René Henrion: On (co-)derivatives of the solution map to a class of generalized equations Alexey Izmailov: Strong regularity and abstract Newton schemes for nonsmooth generalized equations	Marco A. Lopez: Lower semicontinuity of the feasible set mapping of linear systems relative to their domains Nguyen Dong Yen: Codifferentiability of a Karush–Kuhn–Tucker point set map and applications	H 2035
Variational analysis: Variational analysis of optimal value functions and set-valued mappings with applications [Organizer: Mau Nam Nguyen] [p. 224] Messoud Bounkhel: Regularity concepts of perturbed distance functions at points outside of the set in Banach spaces	Christiane Pöschl: TV-denoising and evolution of sets	H 2051
Variational analysis: Variational methods in inverse problems [Organizer: Elena Resmerita] [p. 224] Esther Klann: A Mumford–Shah type approach for tomography Mihaela Pricop-Jeckstadt: Genomic selection and iterative regularization methods		MA 649
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Approximation and online algorithms: Online algorithms [Organizer: Lisa Fleischer] [p. 224] Aleksander Madry: A polylogarithmic-competitive algorithm for the k -server problem Umang Bhaskar: Online mixed packing and covering	Vahab Mirrokni: Simultaneous adversarial and stochastic approximations for budgeted allocation problems	H 3010
Combinatorial optimization: Optimization methods for geometric problems [Organizers: Sándor Fekete and Alexander Kröller] [p. 225] Dan Halperin: Multi-objective path optimization in motion planning: From the particular to the general point-guards problem Cid de Souza: Towards solving to optimality the art gallery with point-guards problem	Alexander Kröller: Practical solutions and bounds for art gallery problems	H 3004
Combinatorial optimization: Recent advances in matching algorithms [Organizer: Piotr Sankowski] [p. 225] Manoj Gupta: Fully dynamic maximal matching in $O(\log n)$ update time Chien-Chung Huang: Efficient algorithms for maximum weight matchings in general graphs with small edge weights	Mohammad Mahdian: Online bipartite matching with random arrivals: An approach based on strongly factor-revealing LPs	H 3005
Combinatorial optimization: Discrete structures and algorithms III [Organizer: Satoru Fujishige] [p. 225] Yusuke Kobayashi: An algorithm for finding a maximum t -matching excluding complete partite subgraphs	Kiyohito Nagano: Size-constrained submodular minimization through minimum norm base	H 3008
Combinatorial optimization: Arborescences [p. 226] Attila Bernáth: Covering minimum cost arborescences	Mikael Call: A polyhedral analysis of a unique shortest path routing polytope	H 3012
Combinatorial optimization: Scheduling and network flows over time [Organizer: Martin Skutella] [p. 226] Alberto Marchetti-Spaccamela: Universal sequencing on an unreliable machine Mario Leston-Rey: Packing entering sets in kernel systems	Jan-Philipp Kappmeier: Flows over time with negative transit times and arc release dates	H 3013
Complementarity and variational inequalities: Algorithms for complementarity and related problems I [p. 226] Artur Pogosyan: Semismooth Newton-type methods for lifted mathematical programs with complementarity constraints Evgeny Uskov: Global convergence of augmented Lagrangian methods applied to optimization problems with degenerate constraints, including problems with complementarity constraints	Walter Morris: Efficient computation of a canonical form for a generalized P -matrix	MA 313
Conic programming: Conic optimization and signal processing applications [Organizer: Anthony Man-Cho So] [p. 227] Senshan Ji: Approximating a KKT point of Schatten p -quasi-norm minimization in polynomial time, with applications to sensor network localization Wing-Kin Ma: Semidefinite relaxation in wireless communications: Forefront developments, advances and challenges	Yang Yang: Multi-portfolio optimization: A variational inequality approach	H 2036
Conic programming: Recent developments of theory and applications in conic optimization part I [Organizers: Hayato Waki and Masakazu Murotamatsu] [p. 227] Muddappa Gowda: On the nonhomogeneity and the bilinearity rank of a completely positive cone Masakazu Murotamatsu: A perturbed sums of squares theorem for polynomial optimization and its applications	Farid Alizadeh: Some geometric applications of abstract algebraic sum-of-squares cones	H 2038

<p>Derivative-free and simulation-based optimization: Recent progress in direct search methods [Organizers: Luís Nunes Vicente and Stefan Wild] [p. 227] Sébastien Le Digabel: The mesh adaptive direct search algorithm with reduced number of directions</p>	<p>[Organizers: José Mario Martínez: Inexact restoration method for derivative-free optimization with smooth constraints Rohollah Garmanjani: Smoothing and worst case complexity for direct-search methods in non-smooth optimization]</p>	<p>H 3003A</p>
<p>Finance and economics: Modern portfolio optimization [p. 228] Süleyman Özekici: Portfolio selection with hyperexponential utility functions</p>	<p>Eligius Hendrix: On finding optimal portfolios with risky assets</p>	<p>H 3021</p>
<p>Finance and economics: Applications in finance [p. 228] Jonas Ekblom: Optimal hedging of foreign exchange risk in uncertain cash flows using stochastic programming</p>	<p>Mathias Barkhagen: An optimization based method for arbitrage-free estimation of the implied risk neutral density surface</p>	<p>H 3027</p>
<p>Game theory: New models and solution concepts I [p. 228] Leqin Wu: A new solution concept for cooperative games</p>	<p>Daniel Granot: Subgame perfect consistent stability</p>	<p>MA 005</p>
<p>Game theory: Software piracy and mastermind [p. 227] Yael Perlman: Software piracy prevention and price determination</p>	<p>Carola Winzen: Playing mastermind with many colors</p>	<p>MA 043</p>
<p>Global optimization: Advances in global optimization III [p. 229] Tibor Csendes: Symbolic simplification of nonlinear optimization problems</p>	<p>Chu Nguyen: The interior exterior approach for linear programming problem</p>	<p>H 2053</p>
<p>Implementations and software: Modeling languages and software III [p. 229] Per Rutquist: Trajectory optimization with TOMLAB/PROPT</p>	<p>Christian Valente: Optimisation under uncertainty: Software tools for modelling and solver support</p>	<p>H 1058</p>
<p>Integer and mixed-integer programming: Topology, clustering and separation [p. 230] Marcia Fampa: MILP formulation for the software clustering problem</p>	<p>Pedro Guillén: Natural languages with the morphosyntactic distance as a topological space</p>	<p>H 2013</p>
<p>Integer and mixed-integer programming: Branch-and-price IV: Primal heuristics [Organizer: Marco Lübbecke] [p. 230] Christian Puchert: Large neighborhood search and diving heuristics in column generation algorithms</p>	<p>François Vanderbeck: Primal heuristics for branch-and-price</p>	<p>H 2032</p>
<p>Integer and mixed-integer programming: Mixed-integer linear and semidefinite programs [Organizer: Marc Pletsch] [p. 230] Sonja Mars: Approaches to solve mixed integer semidefinite programs</p>	<p>Nam Dung Hoang: Steiner tree packing revisited</p>	<p>H 2033</p>
<p>Life sciences and healthcare: Mathematical modeling of disease [p. 231] Ivan Savić: Mathematical modeling of amygdalin isolation from plum kernel using response surface methodology</p>	<p>Rujira Ouncharoen: Stability of HIV aphaeresis model</p>	<p>MA 376</p>
<p>Logistics, traffic, and transportation: Logistics and transportation [Organizer: Arash Asadpour] [p. 231] Arash Asadpour: Rounding by sampling and an $O(\log n / \log \log n)$ approximation algorithm for ATSP</p>	<p>Nitish Korula: Prize-collecting Steiner network problems on planar graphs</p>	<p>H 0106</p>
<p>Logistics, traffic, and transportation: Real-world applications [p. 231] Kaj Holmberg: Planning and routing in networks: Urban snow removal</p>	<p>Rodrigo Branchini: Fleet deployment optimization model for tramp and liner shipping</p>	<p>MA 042</p>
<p>Mixed-integer nonlinear programming: Mixed-integer nonlinear programming [Organizer: Jon Lee] [p. 232] Shmuel Onn: Integer programming in polynomial time via Graver bases</p>	<p>Renata Sotirov: SDP relaxations for the graph partition problem</p>	<p>MA 001</p>

<p>Multi-objective optimization: Preference structures in multi-objective optimization [Organizer: Gabriele Eichfelder] [p. 232] Gabriele Eichfelder: A procedure for solving vector optimization problems with a variable ordering structure</p>	<p>[Organizer: Gabriele Eichfelder] [p. 232] Behnam Soleimani: Approximate solutions of vector optimization with variable order structure</p>	<p>[p. 232] Refail Kasimbeyli: Characterization of properly nondominated elements in vector optimization with variable ordering structures</p>	<p>H 1029</p>
<p>Nonlinear programming: Algorithms and applications II [Organizer: Ya-xiang Yuan] [p. 232] Jinyan Fan: Accelerating the modified Levenberg-Marquardt method</p>	<p>[p. 232] Yanfei Wang: Optimizing inversion methods for seismic imaging</p>	<p>H 0107 Torsten Bosse: Limited memory updating and quadratic overestimation for NLOP</p>	<p>H 0107</p>
<p>Nonlinear programming: Polynomial optimization and semidefinite programming [Organizer: Jiawang Nie] [p. 232] lihong zhi: Computing real solutions of polynomial systems via low-rank moment matrix completion</p>	<p>[p. 232] Cordian Riener: Symmetry in polynomial optimization</p>	<p>H 0110 Markus Schweighofer: The sums of squares dual of a semidefinite program</p>	<p>H 0110</p>
<p>Nonlinear programming: Nonlinear multilevel and domain decomposition methods in optimization [Organizer: Michal Kocvara] [p. 233] Zdenek Dostal: Optimal, massively parallel algorithms for large QP/QPQC problems arising in mechanics</p>	<p>[p. 233] James Turner: Applications of domain decomposition to topology optimization</p>	<p>H 0112 Rolf Krause: Inherently nonlinear decomposition and multilevel strategies for non-convex minimization</p>	<p>H 0112</p>
<p>Nonsmooth optimization: Algorithms for nonsmooth optimization [Organizer: Robert Mifflin] [p. 233] Robert Mifflin: A first step in designing a VU-algorithm for nonconvex minimization</p>	<p>[p. 233] Wellington Oliveira: Exploring accuracy and geometry in level bundle methods</p>	<p>H 1012 Adam Ounorou: Specialized proximal Chebychev center cutting plane algorithm for convex additive functions</p>	<p>H 1012</p>
<p>Optimization in energy systems: Equilibrium models for electricity markets [Organizer: Andy Philpott] [p. 233] Pär Holmberg: Supply function equilibria in networks with transport constraints</p>	<p>[p. 233] Eddie Anderson: When do supply function equilibria exist?</p>	<p>MA 549 Andy Philpott: Competitive equilibrium and risk aversion in hydro-dominated electricity markets</p>	<p>MA 549</p>
<p>Optimization in energy systems: Gas transport in networks [Organizer: Rüdiger Schultz] [p. 234] Martin Schmidt: An extended interior point method for nonsmooth nonlinear optimization in gas networks</p>	<p>[p. 234] Imke Joormann: Analyzing infeasibility in natural gas networks</p>	<p>MA 550 Ralf Gollmer: Stationary gas transport – Structure of the problem and a solution approach</p>	<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Adjoint-based methods and algorithmic differentiation in large scale optimization [Organizer: Andreas Griewank] [p. 234] Nikolai Strogies: A time-labeling approach for open pit mine planning</p>	<p>[p. 234] Emre Özkaya: Automatic differentiation of an unsteady RANS solver for optimal active flow control</p>	<p>H 0111 Stephan Schmidt: Large scale shape optimization</p>	<p>H 0111</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Variational methods in image processing and compressed sensing [Organizer: Weitao Yin] [p. 234] Yiqiu Dong: A convex variational model for restoring blurred images with multiplicative noise</p>	<p>[p. 234] Hong Jiang: Surveillance video processing using compressive sensing</p>	<p>MA 415 Tao Wu: A nonconvex TV^q model in image restoration</p>	<p>MA 415</p>
<p>Robust optimization: Regret with robustness: Models, algorithms and applications [Organizer: Karthik Natarajan] [p. 235] Dongjian Shi: A probabilistic model for minmax regret combinatorial optimization</p>	<p>[p. 235] Andrew Lim: Robust portfolio selection with learning in the framework of relative regret</p>	<p>MA 004 Joline Uchenco: Regret optimization for stochastic inventory models with spread information</p>	<p>MA 004</p>
<p>Sparse optimization and compressed sensing: Variational signal processing – algorithms and applications [Organizer: Junfeng Yang] [p. 235] Wenxing Zhang: On variational image decomposition model for blurred images with missing pixel values</p>	<p>[p. 235] Junfeng Yang: Convergence of a class of stationary iterative methods for saddle point problems</p>	<p>H 1028 Yilun Wang: Sparse signal reconstruction based on iterative support detection</p>	<p>H 1028</p>
<p>Stochastic optimization: Measures of uncertainty [Organizer: Mariada Bertocchi] [p. 235] Francesca Maggioni: Measures of information in multistage stochastic programming</p>	<p>[p. 235] Simone Garatti: The risk of empirical costs in randomized min-max stochastic optimization</p>	<p>MA 141 Alexei Gaivoronski: Stochastic bilevel optimization problems with applications to telecom</p>	<p>MA 141</p>
<p>Stochastic optimization: Chance constrained stochastic optimization [p. 236] Yongjia Song: A branch-and-cut algorithm for the chance-constrained knapsack problem</p>	<p>[p. 236] Jessie Birman: Overall aircraft design based on chance-constrained programming</p>	<p>MA 144 Jianqiang Cheng: Stochastic linear programming with joint chance constraints</p>	<p>MA 144</p>
<p>Telecommunications and networks: Network design [Organizer: Ridha Mahjoub] [p. 236] Viet Hung Nguyen: A direct algorithm for detecting negative cost cycles in undirected graphs</p>	<p>[p. 236] Amal Benhamiche: On the optical multi-band network design problem</p>	<p>H 3002 Raouia Taktak: Models and algorithms for the survivable multilayer network design problem</p>	<p>H 3002</p>

<p>Telecommunications and networks: Robust communication networks [Organizer: Arie Koster] [p. 236] Grit Claßen: A branch-and-price approach for the robust wireless network planning</p>	<p>Daniel Karch: Fiber replacement scheduling</p>	<p>H 3503</p>
<p>Variational analysis: Set-valued convex and quasiconvex duality [Organizer: Andreas Hamel] [p. 237] Carola Schrage: Dini derivatives for vector- and set-valued functions</p>	<p>Samuel Drapeau: Complete duality for convex and quasiconvex set-valued functions</p>	<p>H 2035</p>
<p>Variational analysis: Semi-continuous programming [Organizer: Wilfredo Sosa] [p. 237] Ademir Ribeiro: Fenchel-Moreau conjugation for lower semi-continuous functions</p>	<p>Wilfredo Sosa: Separation theorems for closed sets</p>	<p>H 2051</p>
<p>Friday 10:30–12:00</p>		
<p>Approximation and online algorithms: Approximation of vehicle routing problems [p. 237] Martijn van Brink: Express delivery of packages</p>	<p>Ignacio Vargas: An efficient decision making process for vehicle operations in underground mining based on a mixed-integer programming model</p>	<p>H 3010</p>
<p>Combinatorial optimization: Approximation algorithms for hard problems [Organizer: Guochuan Zhang] [p. 238] Lin Chen: Approximation algorithms for scheduling parallel machines with capacity constraints</p>	<p>Xudong Hu: New models for network connection problems with interval data</p>	<p>H 3004</p>
<p>Combinatorial optimization: Combinatorial optimization in logistics [Organizer: Erwin Pesch] [p. 238] Jens Schulz: Explanation algorithms in cumulative scheduling</p>	<p>Erwin Pesch: A branch-and-bound algorithm for the acyclic partitioning problem</p>	<p>H 3005</p>
<p>Combinatorial optimization: Algorithms in claw-free graphs [Organizer: Gautier Stauffer] [p. 238] Matthias Mäch: Domination when the stars are out – Efficient decomposition of claw-free graphs</p>	<p>Paolo Nobile: A decomposition algorithm for the weighted stable-set problem in claw-free graphs</p>	<p>H 3008</p>
<p>Combinatorial optimization: Cliques, stable sets, and perfect graphs [p. 239] Maribel Montenegro: On the N-index of the stable set polytope related to antiwebs</p>	<p>Claudia Snels: Minimum weighted clique cover on strip-composed perfect graphs</p>	<p>H 3012</p>
<p>Combinatorial optimization: Extended formulations [p. 239] Paolo Serafini: Compact formulations for large-scale LP problems</p>	<p>Ralf Borndörfer: Configuration models for solving integrated combinatorial optimization problems</p>	<p>H 3013</p>
<p>Complementarity and variational inequalities: Algorithms for complementarity and related problems II [p. 240] Mauro Passacantando: Gap functions and penalization for solving equilibrium problems with nonlinear constraints</p>	<p>Raman Sanyal: Deciding polyhedrality of spectrahedra</p>	<p>MA 313</p>
<p>Conic programming: Algebraic geometry and conic programming, part I [Organizers: Lek-Heng Lim and Cordian Riener] [p. 240] Tim Netzer: Describing the feasible sets of semidefinite programming</p>	<p>Victor Magron: Certification of inequalities involving transcendental functions using semi-definite programming.</p>	<p>H 2036</p>
<p>Conic programming: Recent developments of theory and applications in conic optimization part II [Organizers: Hayato Waki and Masakazu Muramatsu] [p. 240] Mirai Tanaka: Numerical computation of a facial reduction algorithm and an inexact primal-dual path-following method for doubly nonnegative optimization problems</p>	<p>Victor Magron: Certification of inequalities involving transcendental functions using semi-definite programming.</p>	<p>H 2038</p>
<p>Derivative-free and simulation-based optimization: MINLP and constrained derivative-free optimization on thin domains Francisco Sobral: Constrained derivative-free optimization on thin domains</p>	<p>Luis Nunes Vicente) [p. 240] Joshua Griffin: A parallel hybrid derivative-free SAS procedure for MINLP</p>	<p>H 3003A</p>

<p>Finance and economics: Portfolio selection problems [p. 241] Constanta Radulescu: Portfolio selection models with complementarity constraints</p>	<p>Marius Radulescu: The efficient frontiers of mean-variance portfolio selection problems</p>	<p>H 3021</p>
<p>Finance and economics: Optimal control [p. 241] Arindum Mukhopadhyay: A socio-economic production quantity (SEPQ) model for imperfect items with pollution control and varying setup costs</p>	<p>Yuichi Takano: Control policy optimization for dynamic asset allocation by using kernel principal component analysis</p>	<p>H 3027</p>
<p>Game theory: New models and solution concepts II [p. 242] Ming Hu: Existence, uniqueness, and computation of robust Nash equilibrium in a class of multi-leader-follower games</p>	<p>Silvia Schwarze: Equilibria in generalized Nash games with applications to games on polyhedra</p>	<p>MA 005</p>
<p>Game theory: Algorithmic game theory (Organizer: Azarakhsh Malekian) [p. 242] Brendan Lucier: Strategyproof mechanisms for competitive influence in social networks</p>	<p>Nicole Immortica: Social networks and segregation</p>	<p>MA 043</p>
<p>Global optimization: Recent advances in nonconvex quadratic programming with random data (Organizer: Jiming Peng) [p. 242] Nicolas Gillis: Fast and robust recursive algorithm for separable nonnegative matrix factorization</p>	<p>Jiming Peng: Quadratic optimization with separable objective and a single quadratic and box constraint</p>	<p>H 0110</p>
<p>Global optimization: Advances in global optimization IV [p. 243] Syuuji Yamada: Global optimization methods utilizing partial separating hyperplanes for a canonical dc programming problem</p>	<p>Paul Krokhmal: Asymptotic properties of random multidimensional assignment problems</p>	<p>H 2053</p>
<p>Implementations and software: Open source software for modeling and optimization (Organizer: Theodore Ralphs) [p. 243] Gus Gassmann: Optimization services: Connecting algebraic modelling languages to several solvers using a web-aware framework</p>	<p>John Forrest: A bit of CLP (accelerated?)</p>	<p>H 1058</p>
<p>Integer and mixed-integer programming: Integer programming in data mining (Organizer: Dolores Romero Morales) [p. 243] Yufeng Liu: Optimization issues on some margin-based classifiers</p>	<p>James Brooks: Counting misclassifications: Robust support vector machines via integer programming</p>	<p>H 2013</p>
<p>Integer and mixed-integer programming: Matheuristics (Organizer: Marco Boschetti) [p. 243] José Valério de Carvalho: SearchCot algorithms for the level bin packing problem</p>	<p>Marco Boschetti: A Lagrangian heuristic for the sprint planning in agile methods</p>	<p>H 2032</p>
<p>Integer and mixed-integer programming: Integer programming approaches to job scheduling (Organizer: Jeff Linderoth) [p. 244] Valentina Cacchiani: Fixed job scheduling with resource constraints</p>	<p>Riley Clement: A big-bucket time-indexed formulation for nonpreemptive single machine scheduling problems</p>	<p>H 2033</p>
<p>Life sciences and healthcare: Model discrimination and experimental design [p. 244] Max Nattermann: A quadratic approximation of confidence regions</p>	<p>Alexandra Herzog: Discrimination of competitive model candidates for reversals in bacterium <i>Myxococcus xanthus</i></p>	<p>MA 376</p>
<p>Logistics, traffic, and transportation: Optimizing robot welding cells (Organizers: Jörg Rambu and Martin Skutella) [p. 245] Jürgen Pannek: Collision avoidance via distributed feedback design</p>	<p>Cornelius Schwarz: The laser-sharing problem with fixed tours</p>	<p>H 0106</p>
<p>Logistics, traffic, and transportation: Disruption management [p. 245] Stephen Maher: Integrated airline recovery problem on a minimal disruption neighbourhood</p>	<p>Kazuhiro Kobayashi: Alternative objective functions in ship scheduling for managing supply chain disruption risk</p>	<p>MA 042</p>
<p>Mixed-integer nonlinear programming: Applications of MINLP I (Organizer: Rüdiger Schultz) [p. 245] Claudia Stangl: Feasibility testing for transportation orders in real-life gas networks</p>	<p>Francois Margot: The traveling salesman problem with neighborhoods: MINLP solution</p>	<p>MA 041</p>

<p>Multi-objective optimization: Bilevel optimization and risk management [p. 246] Johannes Jahn: GPU implementation of a multiobjective search algorithm</p>	<p>Joerg Fliege: Reformulations of multiobjective bilevel problems</p>	<p>Frank Heyde: Set-valued average value at risk</p>	<p>H 1029</p>
<p>Nonlinear programming: Optimality conditions and constraint qualifications [Organizer: José Mario Martínez] [p. 246] Maria Maciel: A trust region algorithm for the nonconvex unconstrained vector optimization problem</p>	<p>Paulo Silva: Constant positive generators: A new weak constraint qualification with algorithmic applications</p>	<p>Santosh Srivastav: Fritz John duality in the presence of equality and inequality constraints</p>	<p>H 0107</p>
<p>Nonlinear programming: Complexity issues in optimization [p. 246] Stefan König: Norm maximization is $W[1]$-hard</p>	<p>Claudio Santiago: An efficient algorithm for the projection of a point on the intersection of two hyperplanes and a box in \mathbb{R}^n</p>	<p>Jianming Shi: A computational geometric approach for solving linear programming: Toward strong polynomial</p>	<p>H 0112</p>
<p>Nonsmooth optimization: Topics in nonsmooth nonconvex optimization [p. 247] Wilhelm Freire: Interior epigraph directions method for nonsmooth and nonconvex optimization via generalized augmented Lagrangian duality</p>	<p>Izhar Ahmad: Optimality conditions in nondifferentiable multiobjective fractional programming</p>	<p>Jean-Louis Goffin: Solving unconstrained nonconvex programs with ACCPM</p>	<p>H 1012</p>
<p>Optimization in energy systems: Power flow modelling and mechanism design [p. 247] Stephan Lemkens: Structural properties of power grid design</p>	<p>Waqqas Bukhsh: Local solutions of optimal power flow problem</p>	<p>Deepak Bagchi: Optimal combinatorial auction for smart grids with renewable energy resources</p>	<p>MA 549</p>
<p>Optimization in energy systems: Optimal control [p. 247] Jean-Christophe Alais: On managing the hydroelectric production of a dam by means of the viability theory</p>			<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Optimal control of PDEs with advection terms [p. 247] Anis Younes: The Navier-Stokes problem in velocity-pressure formulation : Convergence and optimal control</p>	<p>Sebastian Pfaff: Optimal boundary control for nonlinear hyperbolic conservation laws with source terms</p>	<p>Mohamed Al-Lawatia: A rational characteristic method for advection diffusion equations</p>	<p>H 0111</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Reduced order model based optimization [p. 248] Andreas Schmidt: POD reduced-order modeling in the context of direct-approach optimization</p>	<p>Jane Ghiglieri: Optimal flow control based on POD and MPC for the cancellation of Tollmien-Schlichting waves by plasma actuators</p>	<p>Daniela Koller: Optimal control of hydroforming processes based on POD</p>	<p>MA 415</p>
<p>Robust optimization: A robust optimization approach to stochastic analysis [Organizers: Nataly Youssef and Chaitanya Bandi] [p. 248] Chaitanya Bandi: Optimal design for multi-item auctions: A robust optimization approach</p>	<p>Nataly Youssef: Robust queueing theory</p>	<p>Dimitris Bertsimas: Network information theory via robust optimization</p>	<p>MA 004</p>
<p>Sparse optimization and compressed sensing: Greedy algorithms for sparse optimization [Organizer: Shai Shalev-Shwartz] [p. 248] Pradeep Ravikumar: Nearest neighbor based greedy coordinate descent</p>	<p>Prateek Jain: Orthogonal matching pursuit with replacement using Pyomo and PySP</p>		<p>H 1028</p>
<p>Stochastic optimization: Progressive hedging: Innovations and applications [Organizer: David Woodruff] [p. 249] David Woodruff: Bundling scenarios in progressive hedging</p>	<p>Jia Kang: Parallel solution of structured nonlinear problems using Pyomo and PySP</p>	<p>Jean-Paul Watson: Asynchronous progressive hedging</p>	<p>MA 141</p>
<p>Stochastic optimization: Stochastic network design and reliability [Organizer: Nediako Dimitrov] [p. 249] Paul Kantor: Layered screening at public events: Models and challenges</p>	<p>Christian Klaus: Increasing network reliability by introducing warehouses</p>	<p>Melih Çelik: The post-disaster debris clearance problem with uncertain debris amounts</p>	<p>MA 144</p>
<p>Telecommunications and networks: Optimization modeling of communication networks [Organizers: Michal Pioro and Deep Medhi] [p. 250] Michal Pioro: On a survivable network design problem with one or two failing links and elementary path-flows</p>	<p>Giuliana Carallo: A network loading problem with shared protection and SRG: Formulations and ILP based hybrid heuristics</p>	<p>Uwe Steglich: Robust multi-layer network design under traffic demand uncertainty</p>	<p>H 3002</p>
<p>Telecommunications and networks: Robust and survivable network design [Organizer: Fabio D'Andreagiovanni] [p. 250] Christian Raack: Cutset inequalities for robust network design</p>	<p>Agustin Pecorari: Models for p-cycle networks design without cycle enumeration</p>	<p>Di Yuan: Cell load coupling in planning and optimization of LTE networks</p>	<p>H 3503</p>

<p>Variational analysis: Variational-analytic foundations of sensitivity analysis [p. 250] Shanshan Zhang: Partial smoothness, tilt stability, and generalized Hessians</p>	<p>[p. 250] Iqbal Husain: On second-order Fritz John type duality for variational problems</p>	<p>H 2035</p>
<p>Variational analysis: Generalized differentiation and applications (Organizers: Vera Roshchina and Robert Baier) [p. 251] Diethard Pallaschke: Quasidifferentiable calculus and minimal pairs of compact convex sets</p>	<p>[p. 251] Vera Roshchina and Robert Baier: Subgradient methods in nonconvex nonsmooth optimization</p>	<p>H 2051</p>
<p>Friday 13:15–14:45</p>		
<p>Approximation and online algorithms: Scheduling and online algorithms [p. 251] Liliana Grigoriu: Scheduling on uniform processors with at most one downtime on each machine</p>	<p>[p. 251] Truls Flatberg: Online bin covering with lookahead and bounded space</p>	<p>H 3010</p>
<p>Combinatorial optimization: Packing, covering and domination I (Organizer: Annegret Wagler) [p. 251] Annegret Wagler: Generalized row family inequalities for the set covering polyhedron</p>	<p>[p. 251] Annegret Wagler: The identifying code polyhedron of cycles</p>	<p>H 3004</p>
<p>Combinatorial optimization: Nonlinear combinatorial optimisation problems I (Organizer: Adam Letchford) [p. 252] Frank Baumann: Exact algorithms for combinatorial optimization problems with submodular objective functions</p>	<p>[p. 252] Adam Letchford: A polyhedral approach to the quadratic matching problem</p>	<p>H 3005</p>
<p>Combinatorial optimization: Vehicle routing [p. 252] Enrico Bartolini: The single-vehicle dial-a-ride problem</p>	<p>[p. 252] Rafael Martinelli: Efficient restricted non-elementary route pricing for routing problems</p>	<p>H 3012</p>
<p>Combinatorial optimization: Facility location (Organizer: Jaroslaw Byrka) [p. 252] Bartosz Rybicki: Improved LP-rounding approximation algorithm for k-level uncapacitated facility location</p>	<p>[p. 252] Jaroslaw Byrka: Improved approximation guarantees for lower-bounded facility location</p>	<p>H 3013</p>
<p>Complementarity and variational inequalities: Variational inequality problems: Analysis and computation (Organizer: Vinayak Shanbhag) [p. 253] Vinayak Shanbhag: On the analysis and solution of stochastic variational inequalities</p>	<p>[p. 253] Vinayak Shanbhag: Estimation of pure characteristics demand models with pricing</p>	<p>MA 313</p>
<p>Conic programming: Algebraic geometry and conic programming, part II (Organizers: Cordian Riener and Lek-Heng Lim) [p. 253] Jiawang Nie: Certifying convergence of Lasserre's hierarchy via flat truncation</p>	<p>[p. 253] Cordian Riener and Lek-Heng Lim: Abstract cones of positive polynomials and sums of squares</p>	<p>H 2036</p>
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<p>Derivative-free and simulation-based optimization: Multiple objectives in derivative-free optimization (Organizers: Stefan Wild and Luís Nunes Vicente) [p. 254] Francesco Rinaldi: Using an exact penalty function for multiobjective Lipschitz programs</p>	<p>[p. 254] Stefan Wild and Luís Nunes Vicente: Efficient cardinality/mean-variance portfolios</p>	<p>H 3003A</p>
<p>Finance and economics: Risk management under probability model misspecification (Organizers: Apostolos Fertis and Victor Demiguel) [p. 254] David Wozabal: Robustifying convex risk measures: A non-parametric approach</p>	<p>[p. 254] Apostolos Fertis and Victor Demiguel: Stock return serial dependence and out-of-sample portfolio performance</p>	<p>H 3021</p>
<p>Finance and economics: Generalized nash equilibrium problems (Organizer: Kenneth Judd) [p. 254] Philipp Renner: Computing generalized Nash equilibria by polynomial programming</p>	<p>[p. 254] Kenneth Judd: Testing rationality: algorithms and complexity</p>	<p>H 3027</p>
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Game theory: Equilibria in congestion games [p. 255] Philipp von Falkenhausen: Optimal cost sharing protocols for matroid congestion games	Thomas Pradeau: Uniqueness of equilibrium on rings	Max Klimm: Existence and computation of equilibria in bottleneck congestion games	MA 043
Global optimization: Algorithms and applications (Organizer: Ernesto G Birgin) [p. 255] Luis Felipe Bueno: Low order-value approach for solving VaR-constrained optimization problems	Simon Konzett: Numerical enclosures of solution manifolds at near singular points Florian Jarre: Solving large scale problems over the doubly nonnegative cone	Marina Andretta: Deterministic and stochastic global optimization techniques for planar covering with ellipses problems	H 1010
Global optimization: Advances in global optimization V [p. 256] Giancarlo Bigi: Beyond canonical DC programs: The single reverse polar problem	Simon Konzett: Numerical enclosures of solution manifolds at near singular points	Zulfiya Gabidullina: Universal measure of the thickness of separator or pseudo-separator for sets of euclidean space	H 2053
Implementations and software: Conic linear programming (Organizer: Christoph Helmberg) [p. 256] Christoph Helmberg: Speeding up the spectral bundle method by solving the quadratic semidefinite subproblems with a PSQMR approach	Florian Jarre: Solving large scale problems over the doubly nonnegative cone	Kim-Chuan Toh: An inexact accelerated proximal gradient method for large scale convex quadratic SDP	H 1058
Integer and mixed-integer programming: Trends in integer programming (Organizer: Jon Lee) [p. 256] Amitabh Basu: A $(k + 1)$ -slope theorem for the k -dimensional infinite group relaxation	Siqian Shen: Biview interdiction and risk-and-return tradeoffs in probabilistic programs with single or multiple chance constraints	Christopher Ryan: Computing pure Nash equilibria in symmetric games	H 2013
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Life sciences and healthcare: Cell biology (Organizer: Stefan Canzar) [p. 257] Xin Gao: Towards automatic NMR protein structure determination	Julian Mestre: Tree-constrained matching	Sandro Andreotti: De novo peptide sequencing with mathematical programming	MA 376
Logistics, traffic, and transportation: Revenue management applications (Organizer: Paat Rusmevichientong) [p. 258] Srikanth Jagabathula: Assortment optimization under general choice	Arnoud den Boer: Simultaneously learning and optimizing in dynamic pricing and revenue management	James Davis: Assortment optimization under variants of the nested logit model	H 0106
Logistics, traffic, and transportation: Optimization in logistics [p. 258] Markus Frey: Column generation for planning the outbound baggage handling at airports	Armin Fügenschuh: Scheduling and routing of fly-in safari airplanes	Julia Funke: A mixed integer program for a variant of the truck and trailer routing problem with time windows	MA 042
Mixed-integer nonlinear programming: Applications of MINLP II (Organizer: Rüdiger Schultz) [p. 258] Wei Huang: Primal heuristics for nonconvex MINLPs modelling optimal operation of water distribution networks	Harald Held: Challenges and requirements for MINLPs in industrial applications	MA 041	
Multi-objective optimization: Portfolio selection [p. 259] Carlos Abad: Portfolio selection with multiple spectral risk constraints		H 1029	
Nonlinear programming: Stability and solution methods (Organizer: Diethard Klatte) [p. 259] Diethard Klatte: Metric regularity versus strong regularity for critical points of nonlinear programs	Diethard Klatte [p. 259] Stephan Bütikofer: Influence of inexact solutions in a lower level problem on the convergence behavior of a nonsmooth newton method	Bernd Kummer: Newton schemes for functions and multifunctions	H 0107
Nonlinear programming: Optimality conditions I [p. 259] Feyzullah Ahmetoğlu: Necessary conditions for a convex programming problem in Banach spaces partially ordered by a cone with empty interior	Kalpna Shukla: Global parametric sufficient optimality conditions for semi-infinite discrete minimax fractional programming involving generalized V - ρ -invex functions	Andrei Dmitruk: Conditions for a weak minimality in optimal control problems with integral equations of Volterra type	H 0112

<p>Nonlinear programming: Fast gradient methods for nonlinear optimization and applications I [Organizer: William Hager] [p. 260] Rui Diao: A sequential quadratic programming method without a penalty function or a filter for general nonlinear constrained optimization</p>	Gerardo Toraldo: On the use of spectral properties of the steepest descent method	MA 004
<p>Nonsmooth optimization: Nonsmooth optimization and applications [Organizer: Dominikus Noll] [p. 260] Dominikus Noll: Non-convex bundle algorithm with inexact sub-gradient and function values</p>	Frank Fischer: An asynchronous parallel bundle method for Lagrangian relaxation	H 1012
<p>Optimization in energy systems: Congestion management and pricing [Organizer: Mette Bjørndal] [p. 260] Endre Bjørndal: Congestion management in the nordic electricity market</p>	Linda Rud: Nodal versus zonal pricing: Market power in day-ahead versus in balancing services	MA 549
<p>Optimization in energy systems: Generation and expansion problems [p. 261] Michael Lindahl: Discrete optimization support system for the collection grid in large offshore wind parks</p>	Roman Cada: Optimizing nuclear fuel reload patterns	MA 550
<p>PDE-constrained optimization and multi-level/multi-grid methods: PDE-constrained optimization problems with non-smooth structures [p. 261] Duy Luong: A multiresolution algorithm for large scale non-smooth convex optimization problems</p>	Caroline Löbhard: Optimal control of elliptic variational inequalities: A mesh-adaptive finite element solver	H 0111
<p>PDE-constrained optimization and multi-level/multi-grid methods: Hierarchical methods for the design of nanoporous materials [Organizer: Robert Lewis] [p. 261] Paul Boggs: Combining multi-grid and domain decomposition as preconditioners for a class of multi-level PDE-constrained optimization problems</p>	Robert Lewis: Using inexact gradients in a multilevel optimization algorithm	MA 415
<p>Sparse optimization and compressed sensing: Structured matrix optimization [Organizer: Inderjit Dhillon] [p. 262] Ewout van den Berg: Phase-retrieval using explicit low-rank matrix factorization</p>	Inderjit Dhillon: Sparse inverse covariance matrix estimation using quadratic approximation	H 1028
<p>Stochastic optimization: Target oriented optimization under uncertainty [Organizer: Melynn Sim] [p. 262] Zhuoyu Long: Managing operational and financing decisions to meet consumption targets</p>	Melynn Sim: Multiple objective satisficing under uncertainty	MA 141
<p>Stochastic optimization: Stochastic algorithms [p. 262] Song Luo: A nonadaptive probabilistic group testing algorithm for detecting consecutive positives of linear DNA library</p>	Madeleine Theile: How crossover helps in pseudo-boolean optimization	MA 144
<p>Telecommunications and networks: Game theoretic concepts in telecommunications [p. 263] Fabian Medel: Optimal regulation with non discriminatory prices in mobile two way access, with call externalities and heterogeneous costumers</p>	Nikolaus Hansen: Information-geometric optimization	H 3002
<p>Telecommunications and networks: Markovian and randomized techniques for network optimization [p. 263] Olivier Feroq: Polyhedral and ergodic control approaches to PageRank optimization and spam detection</p>	Jonatan Krolikowski: Game theoretic model for the downlink in cellular mobile networks: Nash equilibria and algorithmic convergence	H 3503
<p>Variational analysis: Optimization in infinite dimensional spaces [Organizer: Alexander Zaslavski] [p. 263] Joël Blot: Discrete-time Pontryagin principles and ordered Banach spaces</p>	Cristobal Guzman: Network congestion control with Markovian multipath routing	H 2035
<p>Variational analysis: Duality in convex optimization [Organizer: Radu Ioan Bot] [p. 263] Ernő Csetnek: Conjugate duality and the control of linear discrete systems</p>	Elena Resmerita: A discrepancy principle for the Augmented Lagrangian Method	H 2051
<p>Variational analysis: Duality in convex optimization [Organizer: Radu Ioan Bot] [p. 263] Ernő Csetnek: Conjugate duality and the control of linear discrete systems</p>	Sorin-Mihai Grad: Classical linear vector optimization duality revisited	H 2051

Friday 15:15–16:45

<p>Approximation and online algorithms: Routing and shortest paths [Organizer: Nicole Megow] [p. 264] Vincenzo Bonifaci: Physarum can compute shortest paths</p>	<p>[Organizer: Nicole Megow] [p. 264] Jannik Matuschke: Approximation algorithms for capacitated location routing</p>	<p>H 3010</p>
<p>Combinatorial optimization: Packing, covering and domination II [Organizer: Annegret Wagler] [p. 264] Arnaud Pecher: On the theta number of powers of cycle graphs</p>	<p>[Organizer: Annegret Wagler] [p. 264] Silvia Bianchi: The disjunctive rank of the stable set polytope of web graphs</p>	<p>H 3004</p>
<p>Combinatorial optimization: Nonlinear combinatorial optimization problems II [Organizer: Christoph Buchheim] [p. 264] Franklin Djeumou Fomeni: A dynamic programming heuristic for the quadratic knapsack problem</p>	<p>[Organizer: Christoph Buchheim] [p. 264] Ruth Hübner: Ellipsoid bounds for convex quadratic integer programming</p>	<p>H 3005</p>
<p>Combinatorial optimization: Faster algorithms for network flow problems [Organizer: James Orlin] [p. 265] James Orlin: Max flows in $O(nm)$ time and sometimes less</p>	<p>[Organizer: James Orlin] [p. 265] Yahav Nussbaum: Multiple-source multiple-sink maximum flow in directed planar graphs in near-linear time</p>	<p>H 3008</p>
<p>Combinatorial optimization: Graph optimization problems in the streaming model [Organizer: Anand Srivastav] [p. 265] Christian Konrad: On the order of graph streams</p>	<p>[Organizer: Anand Srivastav] [p. 265] Lasse Kliemann: $(1 + 1/k)$-Approximate maximum matching in bipartite graph streams in $O(k^5)$ passes and improvements</p>	<p>H 3012</p>
<p>Combinatorial optimization: Flows, cuts, and sparsifiers [Organizer: Lisa Fleischer] [p. 266] Nicholas Harvey: Graph sparsifiers</p>	<p>[Organizer: Lisa Fleischer] [p. 266] Jonathan Kelner: Electrical flows, linear systems, and faster approximations of maximum flows, minimum s-t cuts, and multicommodity flows in undirected graphs</p>	<p>H 3013</p>
<p>Complementarity and variational inequalities: Contraction methods for separable convex optimization in the frame of VIs [Organizer: Bingsheng He] [p. 266] Guoyong Gu: Customized proximal point algorithms: A unified approach</p>	<p>[Organizer: Bingsheng He] [p. 266] Xingju Cai: ADM based customized PPA for separable convex programming</p>	<p>MA 313</p>
<p>Conic programming: Algebraic geometry and conic programming, part III [Organizers: Markus Schweighofer and Lek-Heng Lim] [p. 266] Caroline Uhler: Maximum likelihood estimation in Gaussian graphical models from the perspective of convex algebraic geometry</p>	<p>[Organizers: Markus Schweighofer and Lek-Heng Lim] [p. 266] Thorsten Theobald: Containment problems for polytopes and spectrahedra</p>	<p>H 2036</p>
<p>Conic programming: Algebraic symmetry in semidefinite programming [Organizer: Etienne De Klerk] [p. 266] Etienne De Klerk: Improved lower bounds on crossing numbers of graphs via semidefinite programming</p>	<p>[Organizer: Etienne De Klerk] [p. 266] Marianna Eisenberg-Nagy: Symmetry in RL t cuts for the quadratic assignment and standard quadratic optimization problems</p>	<p>H 2038</p>
<p>Derivative-free and simulation-based optimization: Novel applications of derivative-free and simulation-based optimization for determining the surface structure of nanosystems [Organizers: Luis Nunes Vicente and Stefan Wild] [p. 267] Juan Meza: Derivative-free optimization methods for determining the surface structure of nanosystems</p>	<p>[Organizers: Luis Nunes Vicente and Stefan Wild] [p. 267] Annick Sartenaer: Derivative-free optimization for large-scale nonlinear data assimilation problems</p>	<p>H 3003A</p>
<p>Finance and economics: Optimization in financial markets [Organizer: Teemu Pennanen] [p. 267] John Schoenmakers: Multilevel primal and dual approaches for pricing American options</p>	<p>[Organizer: Teemu Pennanen] [p. 267] Dirk Becherer: Optimal sparse portfolios in continuous time</p>	<p>H 3021</p>
<p>Finance and economics: Decision making [p. 267] Marta Villami: Modelling and simulation of social segmentation with individual and competitive parameters</p>	<p>Deepak Kumar: Simultaneous optimization problems in gambling strategies</p>	<p>H 3027</p>
<p>Game theory: Learning and computation for game-theoretic problems [Organizer: Vinayak Shanbhag] [p. 268] W. Ross Morrow: Computing equilibria in regulated differentiated product market models</p>	<p>[Organizer: Vinayak Shanbhag] [p. 268] Angela Nedich: A gossip algorithm for aggregative games on graphs</p>	<p>MA 005</p>

Game theory: Analysis of equilibria in noncooperative games [Organizer: Marc Uetz] [p. 268] Martin Hofer: Contribution games in networks	Jasper de Jong: Decentralized mechanisms for throughput scheduling	MA 043
Global optimization: Structural aspects of global optimization [Organizer: Oliver Stein] [p. 269] Georg Still: Minimization of nonconvex quadratic functions on special feasible sets Tomas Bajbar: Nonsmooth versions of Sard's theorem	Dominik Dorsch: Local models in equilibrium optimization	H 0110
Global optimization: Advances in global optimization VI [p. 269] Holger Diedam: Global optimal control using direct multiple shooting Daniel Aloise: A column generation algorithm for semi-supervised clustering		H 2053
Implementations and software: Parallel optimization software [Organizer: Jeff Linderoth] [p. 269] Katsuki Fujisawa: High-performance general solver for extremely large-scale semidefinite programming problems Yuji Shinano: ParaSCIP and FiberSCIP – Parallel extensions of SCIP	Cynthia Phillips: PICO's new hierarchical branch-and-bound system for massively parallel IP	H 1058
Integer and mixed-integer programming: Symmetry issues in integer programming [Organizer: Volker Kaibel] [p. 269] Marc Pietsch: A computational comparison of symmetry handling methods in integer programming Matteo Fischetti: Orbital shrinking	Jim Ostrowski: Dominance-strengthened symmetry breaking constraints in the unit commitment problem	H 2013
Integer and mixed-integer programming: Integer points in polytopes II [Organizers: Michael Joswig and Günter M. Ziegler] [p. 270] Benjamin Nill: Recent developments in the geometry of numbers of lattice polytopes Andreas Pfaffenholz: Permutation polytopes	Alexander Kasprzyk: Riemannian polytopes	H 2032
Integer and mixed-integer programming: Decomposition methods and applications [Organizer: Joe Naoum-Sawaya] [p. 270] Joe Naoum-Sawaya: A Benders decomposition approach for the critical node selection problem Emre Celebi: An approximation algorithm for Benders decomposition of variational inequality problems	Kerem Akartunali: Radiation treatment planning for volumetric modulated arc therapy [VMAT]: Optimization and heuristics	H 2033
Life sciences and healthcare: Methods from discrete mathematics in systems biology [Organizer: Utz-Uwe Haus] [p. 270] Stefanie Jegelka: On fast approximate submodular minimization and related problems Edward Roualdes: Non-parametric species delimitation based on branching rates	Giovanni Felici: Logic data mining in the presence of noisy data	MA 376
Logistics, traffic, and transportation: Inventory routing [p. 271] Samira Mirzaei: Inventory routing problem for distribution of perishable goods Takayuki Shiina: Inventory distribution problem under uncertainty		H 0106
Logistics, traffic, and transportation: Applications of supply chain [p. 271] Abolfazl Mirzazadeh: A bi-criteria inventory model under stochastic environment with considering perishable costs Stefan Waldherr: Two-stage order sequence planning in shelf-board production	Yehua Wei: Understanding the performance of the long chain and sparse designs in process flexibility	MA 042
Mixed-integer nonlinear programming: Modelling, reformulation and solution of MINLPs [Organizer: Leo Liberti] [p. 271] Marianna de Santis: A method for MINLP problems with simple constraints Leo Liberti: On feasibility-based bounds tightening	Claudia D'Ambrosio: Optimistic modeling of non-linear optimization problems by mixed-integer linear programming	MA 041
Multi-objective optimization: Optimality conditions in multiobjective optimization [Organizer: Akhtar Khan] [p. 272] Qinghong Zhang: Efficiency conditions for semi-infinite multiobjective optimization problems Akhtar Khan: Second-order optimality conditions and sensitivity analysis in set-valued optimization	Baasansuren Jadamba: Regularization of stochastic variational inequalities and comparison of an L_p and a sample-path approach for network problems	H 1029
Nonlinear programming: Decomposition and relaxation methods [p. 272] Quentin Louveaux: Relaxation schemes for the evaluation of a policy in batch mode reinforcement learning Oleg Burdakov: An approach to solving decomposable optimization problems with coupling constraints		H 0107
Nonlinear programming: Optimality conditions II [p. 272] Mourad Naffouti: On the second order optimality conditions for optimization problems with inequality constraints Alexander Strekalovskiy: New mathematical tools for new optimization problems		H 0112
Nonlinear programming: Fast gradient methods for nonlinear optimization and applications II [Organizer: William Hager] [p. 272] Ya-Feng Liu: Max-min fairness linear transceiver design for a multi-user MIMO interference channel William Hager: A primal-dual active set algorithm for nonlinear optimization with polyhedral constraints	Yu-Hong Dai: A perfect example for the BFGS method	MA 004

<p>Optimization in energy systems: Stochastic equilibria in energy markets II [Organizer: Daniel Ralph] [p. 273] Juan Pablo Luna: Finding equilibrium prices for energy markets with clearing conditions</p>	<p>[p. 273] Oge Ozdemir: Generation capacity investments in electricity markets: Perfect competition</p>	<p>Daniel Ralph: Risk averse long term capacity equilibria: An optimization formulation extending MARKAL</p>	<p>MA 549</p>
<p>Optimization in energy systems: MPEC problems and market coupling [p. 273] Bertrand Cornélusse: Coupling European day-ahead electricity markets with COSMOS</p>	<p>[p. 273] Johannes Müller: Linear clearing prices in non-convex European day-ahead electricity markets</p>	<p>Daniel Huppmann: Approximating unit commitment using mathematical programming under equilibrium constraints</p>	<p>MA 550</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: Preconditioning in PDE constrained optimization [Organizer: Roland Herzog] [p. 274] Markus Kollmann: Robust iterative solvers for a class of PDE-constrained optimization problems</p>	<p>[p. 274] John Pearson: Iterative solution techniques for Stokes and Navier-Stokes control problems</p>	<p>Roland Herzog: Reduced order models in preconditioning techniques</p>	<p>H 0111</p>
<p>PDE-constrained optimization and multi-level/multi-grid methods: PDE constrained optimization with uncertain data [Organizer: Volker Schulz] [p. 274] Hanne Tiesler: Stochastic collocation for optimal control problems with stochastic PDE constraints</p>	<p>[p. 274] Claudia Schillings: On the influence of robustness measures on shape optimization with stochastic uncertainties</p>	<p>Volker Schulz: Matthias Heinkenschloss: A trust-region based adaptive stochastic collocation method for PDE constrained optimization with uncertain coefficients</p>	<p>MA 415</p>
<p>Stochastic optimization: Scenario generation in stochastic programming [Organizer: Mihai Anitescu] [p. 274] Sanjay Mehrotra: New results in scenario generation for stochastic optimization problems via the sparse grid method</p>	<p>[p. 274] John Birge: Cut generation for serially dependent multistage stochastic optimization models</p>	<p>Tito Homem-De-Mello: On scenario generation methods for a hydroelectric power system</p>	<p>MA 141</p>
<p>Stochastic optimization: PDE constrained stochastic optimization [Organizer: Rüdiger Schultz] [p. 275] Rüdiger Schultz: Shape optimization under uncertainty via stochastic optimization</p>	<p>[p. 275] Benedict Geihe: A two-scale approach for risk averse shape optimization</p>	<p>Tony Huschto: Solving stochastic optimal control problems by a polynomial chaos approach</p>	<p>MA 144</p>
<p>Telecommunications and networks: Robust network design and applications [Organizer: Christian Raack] [p. 275] Agostinho Agra: The robust vehicle routing problem with time windows</p>	<p>[p. 275] Sara Mattia: The robust network loading problem</p>	<p>Fabio D'Andreagiovanni: On the adoption of multi-band uncertainty in robust network design</p>	<p>H 3503</p>
<p>Variational analysis: Monotone operators [Organizer: Radu Ioan Bot] [p. 275] Radu Ioan Bot: Approaching the maximal monotonicity of bifunctions via representative functions</p>	<p>[p. 275] Marco Rocco: On a surjectivity-type property of maximal monotone operators</p>	<p>Szilárd László: Regularity conditions for the maximal monotonicity of the generalized parallel sum</p>	<p>H 2051</p>

ABSTRACTS

The session codes

Wed. 2. H 3004	Day of the week			
Wed. 2. H 3004	Time block	1 10:30–12.00	2 13:15–14.45	3 15:15–16.45
Wed. 2. H 3004	Room	H Main Building	M Math Building	

Special session

Mon.1.MA 041

Tucker session

Organizer/Chair Daniel Ralph, University of Cambridge · Invited Session

Daniel Ralph, University of Cambridge

Tucker awards ceremony

In this session, the Tucker Prize for an outstanding doctoral thesis will be awarded, followed by presentations by the three finalists.

Approximation & online algorithms

Mon.1.H 3010

Approximation in routing and others

Organizers/Chairs Sylvia Boyd, University of Ottawa; David Shmoys, Cornell University · Invited Session

Hyung-Chan An, EPFL (with Robert Kleinberg, David Shmoys)

Improving Christofides' algorithm for the s - t path TSP

We present a deterministic $\frac{1+\sqrt{5}}{2}$ -approximation algorithm for the s - t path TSP for an arbitrary metric. Given a symmetric metric cost on n vertices including two prespecified endpoints, the problem is to find a shortest Hamiltonian path between the two endpoints; Hoogeveen showed that the natural variant of Christofides' algorithm is a $5/3$ -approximation algorithm for this problem, and this asymptotically tight bound in fact had been the best approximation ratio known until now. We modify this algorithm so that it chooses the initial spanning tree based on an optimal solution to the Held-Karp relaxation rather than a minimum spanning tree; we prove this simple but crucial modification leads to an improved approximation ratio, surpassing the 20-year-old barrier set by the natural Christofides' algorithm variant. Our algorithm also proves an upper bound of $\frac{1+\sqrt{5}}{2}$ on the integrality gap of the path-variant Held-Karp relaxation. The techniques devised in this paper can be applied to other optimization problems as well, including the prize-collecting s - t path problem and the unit-weight graphical metric s - t path TSP.

Frans Schalekamp, The College of William and Mary (with Jiawei Qian, Anke van Zuylen, David Williamson)

On the integrality gap of the subtour LP for the 1,2-TSP

We study the integrality gap of the subtour LP relaxation for the traveling salesman problem in the special case when all edge costs are either 1 or 2. For the general case of symmetric costs that obey triangle inequality, a famous conjecture is that the integrality gap is $\frac{4}{3}$. Little progress towards resolving this conjecture has been made in thirty years, even though there has very recently been exciting progress with new approximation algorithms for special cases of the TSP, as well as for some related problems.

We conjecture that when all edge costs $c_{ij} \in \{1, 2\}$, the integrality gap is $\frac{10}{9}$. We show that this conjecture is true when the optimal subtour LP solution has a certain structure. Under a weaker assumption, which is an analog of a recent conjecture by Schalekamp, Williamson and van Zuylen, we show that the integrality gap is at most $\frac{7}{6}$. When we do not make any assumptions on the structure of the optimal subtour LP solution, we can show that integrality gap is at most $\frac{19}{15} \approx 1.267 < 4/3$; this is the first bound on the integrality gap of the subtour LP strictly less than $4/3$ known for an interesting special case of the TSP.

David Shmoys, Cornell University (with Maurice Cheung)

A primal-dual approximation algorithm for min-sum single-machine scheduling problems

We consider the following single-machine scheduling problem, which is often denoted $1||\sum f_j$: we are given n jobs to be scheduled on a single machine, where each job j has an integral processing time p_j , and there is a nondecreasing, nonnegative cost function $f_j(C_j)$ that specifies the cost of finishing j at time C_j ; the objective is to minimize $\sum_{j=1}^n f_j(C_j)$. Bansal & Pruhs recently gave the first constant approximation algorithm and we improve on their 16-approximation algorithm, by giving a primal-dual pseudo-polynomial-time algorithm that finds a

solution of cost at most twice the optimal cost, and then show how this can be extended to yield, for any $\epsilon > 0$, a $(2 + \epsilon)$ -approximation algorithm for this problem. Furthermore, we generalize this result to allow the machine's speed to vary over time arbitrarily, for which no previous constant-factor approximation algorithm was known.

Combinatorial optimization

Mon.1.H 3004

Combinatorial optimization in chip design I

Organizer/Chair Stephan Held, University of Bonn · Invited Session

Igor Markov, University of Michigan (with Myung-Chul Kim)

A primal-dual Lagrange optimization for VLSI global placement

We propose a projected subgradient primal-dual Lagrange optimization for global placement, that can be instantiated with a variety of interconnect models. It decomposes the original non-convex problem into "more convex" sub-problems. It generalizes the recent SimPL, SimPLR and Ripple algorithms and extends them. Empirical results on the ISPD 2005 and 2006 benchmark suites confirm the superiority of this technique compared to prior art.

Markus Struzyna, Research Institute for Discrete Mathematics, Bonn University

Quadratic and constrained placement in chip design: Global flows and local realizations

The classical large scale placement problem is a key step in chip design. Given a finite set of modules connected by nets, the task is to find overlap-free positions to the modules in such a way that the overall net length is minimized. This talk presents a quadratic, partitioning-based placement algorithm which is able to handle non-convex and overlapping position constraints to subsets of modules, the *movebounds*. The key routine of our algorithm is the flow-based partitioning which combines a global MinCostFlow model for computing directions with extremely fast and highly parallelizable local realization steps. Despite its global view, the size of the MinCostFlow instance is only linear in the number of partitioning regions and does not depend on the number of cells. We prove that our partitioning scheme finds a (fractional) solution for any given placement or decides in polynomial time that none exists.

Ulrich Brenner, University of Bonn

Fractional versus integral flows: A new approach to VLSI legalization

In VLSI placement legalization, a large set of rectangular cells with the same height is given. The cells are spread over a rectangular area but may still overlap, and the task is to arrange them overlap-free into rows such that the cells' movement is minimized. If we relax the problem by allowing to move fractions of cells, this leads to a minimum-cost flow formulation. Several legalization algorithms are based on that idea. However, in the end we have to get rid of the relaxation since cells cannot be split. Most approaches just round the flow solution and then iterate the whole process.

Our algorithm is based on the *Successive-Shortest Path Algorithm* which iteratively augments flow along paths, but we ensure that only augmentations are considered that can be realized exactly by cell movements. Hence, the method avoids realization problems which are inherent to previous flow-based legalization algorithms.

We compare our approach to legalization tools from industry and academia by experiments on recent real-world designs and public benchmarks. The results show that we are faster and produce significantly smaller movements than any other tool.

Combinatorial optimization

Mon.1.H 3005

Triangulations

Organizer/Chair Lionel Pournin, EFREI · Invited Session

Lionel Pournin, EFREI

The flip-graph of the 4-dimensional cube is connected

Flip-graph connectedness is established for the vertex set of the 4-

Combinatorial optimization

dimensional cube. This result makes it possible to completely enumerate the triangulations of this vertex set in a reasonable time: it is found that there are 92487256 such triangulations, partitioned into 247451 symmetry classes.

Felix Schmiedl, Technische Universität München

Gromov-Hausdorff distance of finite metric spaces

The Gromov-Hausdorff distance of two compact metric spaces is a measure for how far the two spaces are from being isometric. It is a pseudometric on the space of compact metric spaces and has been extensively studied in the field of metric geometry.

In recent years, a lot of attention has been devoted to computational aspects of the Gromov-Hausdorff distance. One of the most active topics is the problem of shape recognition, where the goal is to decide whether two shapes given as polygonal meshes are equivalent under certain invariances.

In this talk, we will investigate the computational complexity of several decision versions of the problem. By relating it to other well known combinatorial optimization problems like the clique and the graph isomorphism problem, we prove that determining the largest subspaces of two finite metric spaces with a fixed upper bound on the Gromov-Hausdorff distance is not in \mathcal{APX} . Furthermore novel algorithms for the problem will be derived from these results.

Combinatorial optimization

Mon.1.H.3008

Rational convex programs and combinatorial algorithms for solving them

Organizer/Chair Vijay Vazirani, Georgia Tech · Invited Session

Vijay Vazirani, Georgia Tech

Rational convex programs

A nonlinear convex program that always has a rational optimal solution will be called a rational convex program (RCP). The notion is analogous to that of an integral linear program (ILP), i.e., an LP that always has integral optimal solutions. The field of combinatorial optimization is built around problems whose LP-relaxations are ILPs.

Our contention is that in many ways, the situation with RCPs is similar to that of ILPs. In both cases, the existence of much higher quality solution is indicative of combinatorial structure that can not only lead to efficient algorithms but also deep insights that yield unexpected gains. This was certainly the case with ILPs, which led to a very rich theory that underlies not only combinatorics but also the theory of algorithms.

Kamal Jain, eBay Research (with Vijay Vazirani)

Eisenberg-Gale markets: Algorithms and game theoretic properties

We define a new class of markets, the Eisenberg-Gale markets. This class contains Fisher's linear market, markets from the resource allocation framework of Kelly [1997], as well as numerous interesting new markets. We obtain combinatorial, strongly polynomial algorithms for several markets in this class. Our algorithms have a simple description as ascending price auctions. Our algorithms lead to insights into game-theoretic properties of these markets, such as efficiency, fairness, and competition monotonicity. They also help determine if these markets always have rational equilibria. A classification of Eisenberg-Gale markets w.r.t. these properties reveals a surprisingly rich set of possibilities.

Gagan Goel, Google Research (with Vijay Vazirani)

A perfect price discrimination market model, and a rational convex program for it

Motivated by the current market ecosystem of online display advertising, where buyers buy goods through intermediaries, we study a natural setting where intermediaries are allowed to price discriminate buyers based on their willingness to pay. We show that introducing perfect price discrimination via an intermediary into the Fisher model with piecewise-linear, concave (PLC) utilities renders its equilibrium polynomial time computable. Moreover, and surprisingly, its set of equilibria are captured by a convex program that generalizes the classical Eisenberg-Gale program, and always admits a rational solution. We also give a combinatorial, polynomial time algorithm for computing an equilibrium. We note that the problem of computing an equilibrium for the traditional Fisher market with PLC utilities is unlikely to be in P, since it is PPAD-complete.

Mon.1.H.3012

Matching

Chair Sigrid Knust, University of Osnabrück

Sigrid Knust, University of Osnabrück

Scheduling sports tournaments on a single court based on special 2-factorizations

We consider a sports tournament for an odd number of teams where every team plays exactly two matches in each round and all matches have to be scheduled consecutively on a single court. We construct schedules for any number of teams minimizing waiting times by using special 2-factorizations of the complete graph (Hamiltonian 2-factorization, solutions to special cases of the Oberwolfach problem).

Mizuyo Takamatsu, Chuo University, JST CREST (with Naonori Kakimura)

Matching problems with delta-matroid constraints

Given an undirected graph $G = (V, E)$ and a directed graph $D = (V, A)$, the master/slave matching problem is to find a matching of maximum cardinality in G such that for each arc (u, v) in A with u being matched, v is also matched. This problem is known to be NP-hard, but polynomially solvable in a special case where the maximum size of a connected component of D is at most two.

As a generalization of the above polynomially solvable problem, we introduce a class of the delta-matroid matching problem. In this problem, given an undirected graph $G = (V, E)$ and a projection of a linear delta-matroid (V, \mathcal{F}) , we find a maximum cardinality matching M such that the set of the end vertices of M belongs to \mathcal{F} . We first show that it can be solved in polynomial time if the delta-matroid is generic, which enlarges a polynomially solvable class of constrained matching problems. In addition, we design a polynomial-time algorithm when the graph is bipartite and the delta-matroid is defined on one vertex side. This result is extended to the case where a linear matroid constraint is additionally imposed on the other vertex side.

Michael Kapralov, Stanford University (with Ashish Goel, Sanjeev Khanna)

On the communication and streaming complexity of maximum bipartite matching

Consider the following communication problem. Alice and Bob are given a bipartite graph G with $2n$ nodes whose edges are partitioned adversarially into two sets. Alice holds the first set, and Bob holds the second set. Alice sends Bob a message that depends only on her part of the graph, after which Bob must output a matching in G . What is the minimum size of the message that allows Bob to recover a matching of size at least $(1 - \epsilon)$ times the maximum matching in G , as a function of n ? The minimum message size is the one-round communication complexity of approximating bipartite matching, which is also a lower bound on the space needed by a one-pass streaming algorithm to obtain a $(1 - \epsilon)$ -approximation. In this talk we are interested in the best approximation one can obtain with linear communication and space. Prior to our work, only the trivial $1/2$ approximation was known. We show that Alice and Bob can achieve a $2/3$ -approximation with a message of linear size, and then build on our techniques to design a *deterministic* streaming $1 - 1/e$ approximation in a single pass for the case of vertex arrivals. Finally, we show that both results are best possible.

Combinatorial optimization

Mon.1.H.3013

Combinatorial optimization in railways I

Organizer/Chair Ralf Borndörfer, Zuse Institute Berlin · Invited Session

Jun Imaizumi, Toyo University (with Kosuke Hasuike, Susumu Morito, Eiki Shigeta)

A column generation approach for crew rostering problem in a freight railway company in Japan

We consider the Crew Rostering Problem (CRP) in a freight railway company in Japan, "Japan Freight Railway Company" (JR-F). JR-F belongs to "JR Group" including six passenger railway companies and operates freight trains on the lines owned by these passenger railway companies. JR-F covers most of main lines of the passenger railway companies and has to manage their depots of the drivers all over Japan. CRP in this paper is to find rosters of a certain depot provided a set of "pairing", which is a sequence of minimum job units called "trip", is given for the depot. The pairings are sequenced into rosters satisfying various constraints. The objective function is to minimize the number of drivers for performing the pairings. We formulate this problem into the Set Partitioning Problem and demonstrate an application of the column generation method to it. As the exact approach to column generation sub-problems needs much computation effort, we employ an alterna-

tive approach consisting of four steps. We show results of numerical experiments for instances based on the timetable.

Thomas Schlechte, Zuse Institute Berlin (with Ralf Borndörfer, Steven Harrod)
Recent developments in railway track allocation

This talk is about mathematical optimization for the efficient use of railway infrastructure. We address the optimal allocation of the available railway track capacity. This track allocation problem is a major challenge for any railway company. Planning and operating railway transportation systems is extremely hard due to the combinatorial complexity of the underlying discrete optimization problems, the technical intricacies, and the immense sizes of the problem instances. We tackle this challenge by developing novel mathematical models and associated innovative algorithmic solution methods for large scale instances. We present two main features – a novel modeling approach for the macroscopic track allocation problem and algorithmic improvements. Finally, we provide computational studies for real world instances, i.e., the Simplan corridor in Switzerland, and various instances from the literature.

Steffen Weider, Zuse Institute Berlin (with Ralf Borndörfer, Markus Reuther, Thomas Schlechte)

A rapid branching method for the vehicle rotation planning problem

The Vehicle Rotation Planning Problem is to schedule rail vehicles in order to cover the trips of a given timetable by a cost optimal set of vehicle rotations. The Problem integrates several facets of railway optimization: train composition, fleet management, maintenance planning, and regularity aspects. We model this problem as a multi-commodity min-cost-flow hypergraph problem and solve it by integer programming based heuristics.

The core of our algorithm is the Rapid Branching method which also was successfully used to solve track allocation problems and integrated vehicle and duty scheduling problems. The Rapid Branching method can be seen as a very fast heuristical traversal of a branch-and-bound search tree. We also present computational results on very large instances of the vehicle rotation planning problem given by our industrial partner DB Fernverkehr AG, which is the largest intercity railway operator in Germany.

Combinatorial optimization

Mon.1.H 3021

Scheduling algorithms I

Organizer/Chair Nikhil Bansal, Eindhoven University of Technology · Invited Session

Kirk Pruhs, University of Pittsburgh (with Anupam Gupta, Ravishankar Krishnaswamy)

Online primal-dual for non-linear optimization with applications to speed scaling

We give a principled method to design online algorithms (for potentially non-linear problems) using a mathematical programming formulation of the problem, and also to analyze the competitiveness of the resulting algorithm using the dual program. This method can be viewed as an extension of the online primal-dual method for linear programming problems, to nonlinear programs. We show the application of this method to two online speed scaling problems: one involving scheduling jobs on a speed scalable processor so as to minimize energy plus an arbitrary sum scheduling objective, and one involving routing virtual circuit connection requests in a network of speed scalable routers so as to minimize the aggregate power or energy used by the routers. This analysis shows that competitive algorithms exist for problems that had resisted analysis using the dominant potential function approach in the speed scaling literature, and provides alternate cleaner analysis for other known results. This represents another step towards a principled design and analysis of primal-dual algorithms for online problems.

Ola Svensson, EPFL

On the hardness of scheduling with precedence constraints to minimize makespan

We will talk about the recently established reductions from a bipartite (and k -partite) ordering problem to two classical scheduling problems: Scheduling with precedence constraints on identical machines to minimize makespan $(P|prec|C_{max})$ and scheduling with precedence constraints on related machines to minimize makespan $(Q|prec|C_{max})$.

Combining our reduction from the bipartite ordering problem with a recent result by Bansal & Khot shows that it is NP-hard to improve upon the classical 2-approximation by Graham '66 for identical machines, assuming a variant of the unique games conjecture.

For related machines, we show that if a generalized version of the bipartite (namely k -partite) ordering problem is hard then $(Q|prec|C_{max})$ does not admit a constant factor approximation algorithm. However, the

hardness of the k -partite ordering problem remains open even if we assume the unique games conjecture.

Cliff Stein, Columbia University (with Kirk Pruhs)

How to schedule when you have to buy your energy

We consider a situation where jobs arrive over time at a data center, consisting of identical speed-scalable processors. For each job, the scheduler knows how much income is lost as a function of how long the job is delayed. The scheduler also knows the fixed cost of a unit of energy. The online scheduler determines which jobs to run on which processors, and at what speed to run the processors. The scheduler's objective is to maximize profit, which is the income obtained from jobs minus the energy costs. We give a $(1 + \epsilon)$ -speed $O(1)$ -competitive algorithm, and show that resource augmentation is necessary to achieve $O(1)$ -competitiveness.

Complementarity & variational inequalities

Mon.1.MA 313

Optimization and equilibrium models in energy systems

Organizer/Chair Jong-Shi Pang, University of Illinois at Urbana-Champaign · Invited Session

Steven Gabriel, University of Maryland (with Sauleh Siddiqui)

A new method for MPECs with a natural gas application

We present a new method for solving MPECs based on SOS1 variables and a reformulation of the complementarity terms. We show two forms of the transformed problem: one using SOS1 variables and the other a penalty term. We present some theoretical results as well as numerical tests on a small energy production problem and a large-scale one for natural gas.

Yueyue Fan, University of California, Davis (with Roger Wets)

A stochastic variational inequality model for estimating traffic demand based on random link flow observations

In this talk, we will discuss a problem of estimating travel demand of a network based on observations of link flow. First, we will show how the estimation problem can be formulated as a stochastic programming problem. The objective is to minimize the expected estimation error, subjected to physical and behavior assumptions of network flow. Next, we will extend the estimation problem to a sensor resource allocation problem, in which the goal is to identify the best sensor deployment strategy to maximize the benefit of information gained from the sensors. The design of numerical solution algorithms will be also discussed. The proposed modeling framework demonstrates a clear linkage between statistical estimation and optimization. From the engineering perspective, this work has the potential to improve the utilization of information technologies.

Yanfeng Ouyang, University of Illinois at Urbana-Champaign (with Yun Bai, Jong-Shi Pang)

Biofuel supply chain design under competitive agricultural land use and feedstock market equilibrium

The rapid expansion of the U.S. biofuel industry diverts a large amount of agricultural crops as energy feedstocks, and in turn affects farm land allocation, food market equilibrium, and agricultural economy. We present game-theoretic models that incorporate farmers' decisions on land use and market choice into the biofuel manufacturers' supply chain design problem (i.e., number and locations of biorefineries, resource procurement prices). A noncooperative bi-level Stackelberg game model and a cooperative game model are developed respectively to address possible business partnership scenarios between feedstock suppliers and biofuel manufacturers. Spatial market equilibrium is utilized to model crop supply and demand and the associated market price variations. We transform the bilevel model into a mixed integer quadratic program, and explore adaptive implementation of linear program relaxation and Lagrangian relaxation. The proposed methodology is illustrated using an empirical case study of the Illinois State, and the computation results reveal interesting insights into optimal land use strategies and supply chain design for the emerging "biofuel economy."

Conic programming

Mon.1.H 2036

Geometry and duality in convex programming

Organizer/Chair Gabor Pataki, UNC Chapel Hill · Invited Session

Hayato Waki, Kyushu University (with Masakazu Muramatsu)

Computation of facial reduction algorithm

Facial reduction algorithm (FRA) generates a smaller conic optimization problem by exploiting the degeneracy in a given conic optimization problem. However, the computation is comparable to solving

the original problem. In addition, the resulting problem may lose the sparsity. In this talk, we show that one can apply FRA effectively by using structure in the original problem. For this, we present some examples, such as SDP relaxation for polynomial optimization and graph partitioning. In particular, we prove that in SDP relaxation for polynomial optimization, some methods for reducing the size of the SDP relaxation problems are partial application of FRA. This is joint work with Professor Masakazu Muramatsu (UEC).

Vera Roshchina, University of Ballarat (with Javier Peña)

Partition and complementarity in multifold conic systems

We consider a homogeneous multifold convex conic system and its dual and show that there is canonical partition of the multifold structure determined by certain complementarity sets associated to the most interior solutions to the two systems. Our results are inspired by and extend the Goldman-Tucker Theorem for linear programming.

Osman Guler, University of Maryland (UMBC)

Efficient first-order methods for convex programming

First-order methods for convex programming use only information about gradients (or subgradients). They are especially useful for large-scale problems since each iteration is cheap, memory requirements are low, and the convergence rates do not depend on the dimension of the problem. After the pioneering work by Polyak and later on by Yudin-Nemirovskii, and especially after Nesterov's work on optimal first-order method which emulates the conjugate gradient method, there has been a lot of recent interest in such methods. These algorithms can be extended to optimization problems with constraints, minimax problems, and have connections with the proximal-point methods. However, certain aspects of the algorithms are somewhat mysterious and not well understood. In our talk, we will explore the theoretical underpinnings of these methods and find new applications for them.

Conic programming

Mon.1.H 2038

Applications of semidefinite optimization

Organizer/Chair Miguel Anjos, École Polytechnique de Montreal · Invited Session

Henry Wolkowicz, University of Waterloo

Taking advantage of degeneracy in cone optimization with applications to sensor network localization and molecular conformation

The elegant theoretical results for strong duality and strict complementarity for linear programming, LP, can fail for cone programming over nonpolyhedral cones. Surprisingly, this happens for many instances of semidefinite programming, SDP, problems that arise from relaxations of hard combinatorial problems. Rather than being a disadvantage, we show that this degeneracy can be exploited. In particular, several huge instances of SDP completion problems can be solved quickly and to extremely high accuracy. We illustrate this on the sensor network localization and Molecular conformation problems.

Philipp Hungerländer, Alpen-Adria-Universität Klagenfurt (with Miguel Anjos, Franz Rendl)

Semidefinite optimization approaches to some facility layout problems

Facility layout is concerned with the optimal location of departments inside a plant according to a given objective function reflecting transportation and construction costs of a material-handling system. The Multi-Row Facility Layout Problem is concerned with optimizing the placement of departments along one or several rows. The Directed Circular Facility Layout Problem searches for the optimal arrangement of departments on a circle and contains several layout problems extensively discussed in the literature, namely the Equidistant Unidirectional Cyclic Layout Problem, the Balanced Unidirectional Cyclic Layout Problem and the Directed Circular Arrangement Problem, as special cases. We show that all these layout problems can be modeled as Quadratic Ordering Problems and hence solved to global optimality using a general semidefinite programming approach. We report optimal solutions for several single-row instances from the literature with up to 42 departments that remained unsolved so far. Furthermore we provide high-quality global bounds for double-row instances with up to 16 departments and optimal arrangements for directed circular instances with up to 80 departments.

Manuel Vieira, Nova University of Lisbon (with Miguel Anjos)

Relationships between minimal unsatisfiable subformulas and semidefinite certificates of infeasibility

It is known that if the semidefinite programming (SDP) relaxation of a satisfiability (SAT) instance is infeasible, then the SAT instance is unsatisfiable. Moreover, when the SDP relaxation is infeasible, we can exhibit a proof in the form of an SDP certificate of infeasibility. We can

extract information about the SAT instance from the SDP certificate of infeasibility. In particular, we show how the SDP certificate of infeasibility can provide information about minimal unsatisfiable sub-formulas.

Constraint programming

Mon.1.H 3003A

Constraint-based scheduling

Organizer/Chair Petr Viliam, IBM Czech Republic · Invited Session

Andre Cire, Carnegie Mellon University (with Willem van Hoeve)

MDD propagation for disjunctive scheduling

Disjunctive scheduling refers to a wide range of problems in which activities must be scheduled on a resource capable of processing only one operation at a time. Constraint-based techniques, such as edge finding and not-first/not-last rules, have been a key element in successfully tackling large and complex disjunctive scheduling problems in recent years. In this work we investigate new constraint propagation methods based on limited-width Multivalued Decision Diagrams (MDDs), which represent a relaxation of the feasible sequences of activities that must be scheduled on the resource. We present theoretical properties of the MDD encoding and describe filtering and refinement operations that strengthen the relaxation it provides. Furthermore, we provide an efficient way to integrate the MDD-based reasoning with state-of-the-art propagation techniques for scheduling. Experimental results indicate that the MDD propagation can outperform existing domain filters especially when minimizing sequence-dependent setup times, in certain cases by several orders of magnitude.

Philippe Laborie, IBM

Conditional interval variables: A powerful concept for modeling and solving complex scheduling problems

Scheduling is not only about deciding when to schedule a predefined set of activities. Most of real-world scheduling problems also involve selecting a subset of activities (oversubscribed problems) and a particular way to execute them (resource or mode allocation, alternative recipes, pre-emptive activity splitting, etc.). We introduce the notion of a conditional interval variable in the context of Constraint Programming (CP) and show how this concept can be leveraged to model and solve complex scheduling problems involving both temporal and non-temporal decisions. The presentation will be illustrated with IBM ILOG CPLEX CP Optimizer, a CP based optimization engine implementing this concept.

Finance & economics

Mon.1.H 3027

Applications of stochastic programming to finance and insurance

Organizer/Chair Giorgio Consigli, University of Bergamo · Invited Session

Andrea Consigli, University of Palermo (with Angelo Carollo, Alessandro Staino)

Convex lower bounding to generate multi-asset, arbitrage-free, scenario trees

Simulation models of economic and financial factors are nowadays widely used to support decisions or to assess risk exposures. An extensive literature on scenarios generation is available whose main aim is to build trees with the least number of nodes, while ensuring a given level of accuracy in describing the joint probability distribution of the process.

There is, however, another important issue that is usually overlooked or, worse, ignored: the no-arbitrage restriction.

A possible solution, relatively to the moment matching approach, is to add the no-arbitrage restriction to the set of equations describing the moments of the multivariate distributions, with the shortcoming, however, of worsening the numerical stability and precision of the solution.

The aim of our analysis is to provide a new solution method for the moment matching model to overcome the limitation raised above. We re-formulate the problem of finding all the solutions of a set of non-linear equations as a global optimization problem. We then focus on new convex lower bounding techniques to provide a more stable and reliable approach to stochastic tree generation.

Nalan Gulpinar, Warwick Business School (with Ethem Canakoglu, Dessislava Pachamanova)

Robust investment decisions for asset liability management

In this paper, we present stochastic and robust models for multi-period Asset Liability Management (ALM) problem. ALM involves the management of risks that arise due to mismatches between the assets and liabilities. Stochastic optimization models focus on finding optimal investment decisions over a set of scenarios for the future returns on the assets and the liabilities of the company. Robust approach is introduced to minimize the risks that arise due to the estimation errors of uncertainty on asset returns and liabilities. Computational experiments

using real data are presented to compare the performance of different formalizations of the problem.

Giorgio Consigli, University of Bergamo (with Massimo di Tria, Vittorio Moriggia, Davide Musitelli, Angelo Uristani)

Institutional asset-liability management for a large P&C insurance company

We present an asset-liability management problem for a large insurance company based on a real world development. A 10 year problem is formulated as a stochastic quadratic program with a multicriteria objective function based on short, medium and long term targets. The investment universe includes fixed-income, real estate and equity investment plus alternative investments such as private equity, renewable energy, infrastructures and commodities with dedicated stochastic models. Liabilities and insurance reserves are inflation adjusted and the management aims at controlling the risk exposure while achieving short and medium term goals without jeopardising the long term business sustainability.

Game theory

Mon.1.MA 043

Games in networks

Organizer/Chair Konstantinos Bimpikis, Stanford University · Invited Session

Yann Bramoullé, Laval University (with Mohamed Belhaj, Frédéric Deroian)

Network games under strategic complementarities

In this paper, we study network games with strategic complementarities. Agents are embedded in a fixed network and interact with their network neighbors. They play a game characterized by positive interactions and linear best-replies. We assume that actions are continuous but bounded from above. This means that our game is supermodular. We show that this game always possesses a unique equilibrium. We derive comparative statics, provide a fast algorithm to compute the equilibrium and we characterize the equilibrium explicitly for important families of graphs. We show that action may not be aligned with Bonacich centrality and that interdependence may be broken in the presence of bridges. Overall, we find that the presence of an upper bound on actions strongly affects the outcomes of the game.

Matthew Elliott, Microsoft Research (with Ben Golub)

A network centrality approach to coalitional stability

We study games in which each player simultaneously exerts costly effort that provides different benefits to some of the other players. The goal is to find and describe effort profiles that are immune to coordinated coalitional deviations when such a game is played repeatedly. Formally, these effort profiles are the ones that can be sustained in a strong Nash equilibrium of the repeated game.

First we show, under some assumptions (mainly concavity of utility functions), that an effort profile is Pareto efficient if and only if the spectral radius of an induced ‘benefits’ matrix is one. This ‘benefits’ matrix is a function of the action profile and measures the marginal benefits each agent can confer on each other per unit of marginal cost they incur. Our second result shows that if the right eigenvector of the benefits matrix also corresponds to the action profile, then the action profile is sustainable in a coalitionally robust equilibrium of the repeated game. These results are obtained without parametric assumptions, using the theory of general equilibrium and its relation to the core, along with the Perron-Frobenius spectral theory of nonnegative matrices.

Konstantinos Bimpikis, Stanford University (with Asuman Ozdaglar, Ercan Yildiz)

Competitive marketing strategies over social networks

Recent advances in information technology have allowed firms to gather vast amounts of data regarding consumers’ preferences and the structure and intensity of their social interactions. This paper examines a game-theoretic model of competition between firms, which can target their marketing budgets to individuals embedded in a social network. We provide a sharp characterization of the optimal targeted marketing strategies and highlight their dependence on the consumers’ preferences as well as on the underlying social network structure. In particular, firms find it optimal to allocate their marketing budgets to consumers in proportion to their ‘network centrality’, a measure of social influence. Moreover, we identify network structures for which targeted advertising is more beneficial for the firms and, finally, we show how the difference in the initial budgets affect the outcome of the marketing competition between the firms.

Global optimization

Mon.1.H 2053

Optimization models and methods for computer vision

Organizers/Chairs Jiming Peng, University of Illinois at Urbana-Champaign; Vikas Singh, University of Wisconsin Madison · Invited Session

Vladimir Kolmogorov, IST Austria

Message passing algorithms for MAP-MRF inference

I will consider the problem of computing *maximum a posteriori* configuration in a *Markov Random Field*, or equivalently minimizing a function of discrete variables decomposed as a sum of low-order terms. This task frequently occurs in many fields such as computer vision and machine learning. A popular approach to tackling this NP-hard problem is to solve its LP relaxation. I will talk about message passing algorithms that try to solve the LP, in particular *sequential tree-reweighted message passing* (TRW-S) and its extensions. TRW-S shows good performance in practice and is often used for computer vision problems.

Daniel Cremers, TU Munich (with Antonin Chambolle, Bastian Goldlücke, Kalin Kolev, Thomas Pock, Evgeny Strekalovskiy)

Convex relaxation techniques with applications in computer vision

Numerous computer vision problems can be solved by variational methods and partial differential equations. Yet, many traditional approaches correspond to non-convex energies giving rise to suboptimal solutions and often strong dependency on appropriate initialization. In my presentation, I will show how problems like image segmentation, multiview stereo reconstruction and optic flow estimation can be formulated as variational problems. Subsequently, I will introduce convex relaxation techniques which allow to compute globally optimal or near-optimal solutions. The resulting algorithms provide robust solutions, independent of initialization and compare favorably to spatially discrete graph theoretic approaches in terms of computation time, memory requirements and accuracy.

Maxwell Collins, University of Wisconsin-Madison (with Leo Grady, Vikas Singh, Jia Xu)

Random walks based multi-image segmentation: Quasiconvexity results and GPU-based solutions

We recast the cosegmentation problem using random Walker segmentation as the core segmentation algorithm, rather than the traditional MRF approach adopted in the literature so far. Our formulation is similar to previous approaches in that it also permits cosegmentation constraints which impose consistency between the extracted objects from 2+ images using a nonparametric model. However, several previous nonparametric cosegmentation methods have the limitation that they require one auxiliary node for every pair of pixels that are similar (limiting such methods to describing only those objects that have high entropy appearance models). Our proposed model eliminates this dependence – the resulting improvements are significant. We further allow an optimization scheme exploiting quasiconvexity for model-based segmentation with no dependence on the scale of the segmented foreground. Finally, we show that the optimization can be expressed in terms of operations on sparse matrices which are easily mapped to GPU architecture. We provide a specialized CUDA library for cosegmentation exploiting this special structure, and report experimental results showing these advantages.

Implementations & software

Mon.1.H 1058

Testing environments for machine learning and compressed sensing

Organizer/Chair *Katya Scheinberg, Lehigh University* · Invited Session*Michael Friedlander, University of British Columbia (with Ewout van den Berg)*

Spot: A linear-operator toolbox for Matlab

Linear operators are at the core of many of the most basic algorithms for signal and image processing. Matlab's high-level, matrix-based language allows us to express naturally many of the underlying matrix operations – e.g., computation of matrix-vector products and manipulation of matrices – and is thus a powerful platform on which to develop concrete implementations of these algorithms. Many of the most useful operators, however, do not lend themselves to the explicit matrix representations that Matlab provides. This talk describes the new Spot Toolbox, which aims to bring the expressiveness of Matlab's built-in matrix notation to problems for which explicit matrices are not practical. I will demonstrate features of the toolbox with examples from compressed sensing and image reconstruction.

Katya Scheinberg, Lehigh University

Studying effects of various step selection strategies in first order approaches to compressed sensing and other composite optimization problems

We will discuss theoretical and practical implications of various strategies for choosing the prox parameter in prox gradient methods and related alternating direction methods. We will show extension of existing convergence rates for both accelerated and classical first-order methods. Practical comparison based on a testing environment for L1 optimization will be presented.

Dirk Lorenz, TU Braunschweig (with Christian Kruschel)

Constructing test instances for basis pursuit denoising

The number of available algorithms for the so-called Basis Pursuit Denoising problem (or the related LASSO-problem) is large and keeps growing. Similarly, the number of experiments to evaluate and compare these algorithms on different instances is growing.

In this talk, we discuss a methods to produce instances with exact solutions which is based on a simple observation which is related to the so called source condition from sparse regularization and the so-called dual certificate. We construct such dual-certificate by alternating projections onto convex sets and also by linear programming method. The method have been implemented in a MATLAB package L1TestPack.

Integer & mixed-integer programming

Mon.1.H 2032

Column generation and decomposition

Chair *Richard Lusby, Department of Management Engineering, Technical University of Denmark**Ozgur Ozpeynirci, Izmir University of Economics*

Allocation of proposals to reviewers to facilitate effective ranking: A branch and price approach

One of the key problems for the funding agencies is to determine the proposals that are worth funding. A recent evaluation approach uses the ordinal ranking of the proposals. The approach allocates the proposals to the reviewers and each reviewer provides pairwise comparison of the assigned proposals. The approach uses a set covering IP model to assign the proposals so as to receive the maximum pairwise comparison information considering the capabilities and the preferences of the reviewers. In this study, we develop two new mathematical models for this approach. The size of the first model is polynomial in the number of the proposals. We propose a branch and price algorithm in the second model. We conduct a computational experiment to compare the performances of three models on a set of randomly generated instances.

Richard Lusby, Department of Management Engineering, Technical University of Denmark (with Jesper Larsen, Troels Range)

A column generation approach for solving the patient admission scheduling problem

The Patient Admission Scheduling Problem (PASP) is the problem of assigning patients to hospital rooms in such a way that the preferences of the patients as well as the effectiveness of the medical treatment are maximized. We present a Dantzig-Wolfe decomposition of PASP into a set partitioning master problem and a set of room scheduling problems for the pricing problems; here each column of the master corresponds to a feasible room schedule over the planning horizon. We describe an implementation of the dynamic constraint aggregation methodology proposed by Elhallaoui et al. (2005) to overcome the degeneracy of the master problem and show how this improves the performance

of the column generation significantly. The method is tested on benchmark instances described by Demeester et al. (2008) where we derive tighter lower bounds than those previously reported for several of the instances. The computation time for identifying these lower bounds is, in most cases, significantly less than those presented by Ceshia and Schaerf (2011). A discussion on several branching strategies to integerize the lower bound solution is also provided.

Integer & mixed-integer programming

Mon.1.H 2032

Integer programming algorithms I

Chair *Timm Oertel, ETH Zurich**Chuangyin Dang, City University of Hong Kong (with Yinyu Ye)*

A fixed-point iterative approach to integer programming and distributed computation

Integer programming is concerned with the minimization of a linear function over integer or mixed-integer points in a polytope, which is equivalent under binary search to determining whether there is an integer or mixed-integer point in a polytope. Integer programming is an NP-hard problem and has many applications in economics and management. By constructing an increasing mapping satisfying certain properties, we develop in this paper a fixed-point iterative method for integer programming. The self-dual embedding technique will be applied for a solution to a bounding linear program in the development. Given any polytope, within a finite number of iterations, the method either yields an integer or mixed-integer point in the polytope or proves no such point exists. As a very appealing feature for integer programming, the method can be easily implemented in a distributed way. Furthermore, the method can be applied to compute all integer or mixed-integer points in a polytope. Numerical results show that the method is promising.

Thomas Rehn, University of Rostock (with Katrin Herr, Achill Schürmann)

Exploiting symmetry in integer convex optimization using core points

In this talk we consider symmetric convex programming problems with integrality constraints, that is, problems which are invariant under a linear symmetry group. We define a core point of such a symmetry group as an integral point for which the convex hull of its orbit does not contain integral points other than the orbit points themselves. These core points allow us to decompose symmetric integer convex programming problems. In particular for symmetric integer linear programs we describe two algorithms which make use of this decomposition. We characterize core points for some frequently occurring symmetry groups, in particular for direct products of symmetric groups. We use these results for prototype implementations, which can compete with state-of-the-art commercial solvers on some highly symmetric problems and helped solving an open MIPLIB problem.

Timm Oertel, ETH Zurich (with Christian Wagner, Robert Weismantel)

Convex integer minimization in fixed dimension

We show that minimizing a convex function over the integer points of a bounded convex set is polynomial in fixed dimension. For that, we present a geometric cone-shrinking algorithm. That is, we search for improving integer points within cones, reducing their volume step by step.

Integer & mixed-integer programming

Mon.1.MA 004

Advances in integer programming

Organizer/Chair *Shmuel Onn, Technion – Israel Institute of Technology* · Invited Session*Antoine Deza, McMaster University (with Frédéric Meunier, Tamon Stephen, Feng Xie)*

Combinatorial, computational, and geometric approaches to the colourful simplicial depth

In statistics, there are several measures of the depth of a point p relative to a fixed set S of sample points in dimension d . One of the most intuitive is the simplicial depth of p introduced by Liu (1990), which is the number of simplices generated by points in S that contain p . Obtaining a lower bound for the simplicial depth is a challenging problem. Carathéodory's Theorem can be restated as: The simplicial depth is at least 1 if p belongs to the convex hull of S . Bárány (1982) showed that the simplicial depth is a least a fraction of all possible simplices generated from S . Gromov (2010) improved the fraction via a topological approach. Bárány's result uses a colourful version of the Carathéodory's theorem leading to the associated colourful simplicial depth. We present recent generalizations of the Colourful Carathéodory's theorem due to

Arocha et al. and Homlsen et al. and our strengthening of these. We provide a new lower bound for the colourful simplicial depth improving the earlier bounds of Bárány & Matoušek and of Stephen & Thomas. Computational approaches for small dimension and the colourful linear programming feasibility problem introduced by Bárány & Onn are discussed.

Justo Puerto, Universidad de Sevilla

Ordered weighted average optimization of combinatorial problems

This talk addresses a class of combinatorial optimization models that include among others, bottleneck, k -centrum, general balanced, lexicographic, ordered median and universal optimization. These problems have been analyzed under different names for different authors in the last years [Calvete and Mateos (1998), De la Croce et al. (1999), Lee (1992), Nickel and Puerto (2005), Puerto and Tamir (2005), Punnen and Aneja (1996, 2004), Turner and Hamacher (2011), Turner et al. (2011)]. We study the common framework that underlines those models, present different formulations as integer programs and study their relationships and reinforcements. This approach leads to a branch and cut algorithm applicable to the general problem which is effective up to median size instances. For some specific cases we also analyze specific properties leading to polynomial time combinatorial algorithms.

Matthias Köppe, University of California, Davis (with Nicole Bertine, Michèle Vergne)

A discretization-free FPTAS for polynomial optimization over the mixed-integer points in a class of polytopes of varying dimension

We present a new fully polynomial-time approximation scheme for the problem of optimizing non-convex polynomial functions over the mixed-integer points of a polytope of fixed dimension. This improves upon earlier work that was based on discretization [De Loera, Hemmecke, Köppe, Weismantel, FPTAS for optimizing polynomials . . . , Math. Prog. Ser. A 118 (2008), 273–290]. The algorithm also extends to a class of problems in varying dimension.

The algorithm is based on the study of intermediate sums, interpolating between integrals and discrete sums, initiated by A. Barvinok [2006] and continued by Baldoni, Bertine, De Loera, Köppe, Vergne [Computation of the highest coefficients . . . , Found. Comput. Math. 2012] and Baldoni, Bertine, Köppe, Vergne [Intermediate sums on polyhedra . . . , Mathematika 2012]. For a given polytope P with facets parallel to rational hyperplanes and a rational subspace L , we integrate a given polynomial function h over all lattice slices of the polytope P parallel to the subspace L and sum up the integrals.

This is the culmination of an effort to extend the efficient theory of discrete generating functions to the mixed-integer case.

Integer & mixed-integer programming

Mon.1.MA 042

Recent progress in MIP

Organizer/Chair Oktay Günlük, IBM Research · Invited Session

Marco Molinaro, Carnegie Mellon University (with Sanjeeb Dash, Oktay Günlük)

Strength of cross cuts

Split cuts are among the most important cuts in practice, and modern heuristics can essentially harness their full power. Aiming at improving over split cuts, we study their most natural generalization, cross cuts. We present a theoretical comparison of the strength of the cross-closure and the second split-closure. We also analyze the strength of cross cuts from the important 2-row and basic relaxations and resolve two open questions posed by Dash, Dey and Günlük (2010).

Sanjeeb Dash, IBM T. J. Watson Research Center (with Oktay Günlük)

On t -branch split cuts for mixed-integer programs

We settle a conjecture of Li and Richards on t -branch split cuts, and show that there are mixed-integer programs with $n + 1$ variables which are unsolvable by $(n - 1)$ -branch split cuts, thus extending the well-known 3-variable example of Cook, Kannan and Schrijver which is unsolvable by split cuts.

Egon Balas, Carnegie Mellon University (with Francois Margot, Selvaprabu Nadarajah)

Cut generating points on the boundary of a lattice-free convex set

A new paradigm for generating cuts in mixed integer programming [Balas and Margot, 2011] identifies a set Q of boundary points of a lattice-free convex set S , such that the reverse polar of Q provides valid cuts. We discuss ways of generating such boundary points, and the properties of the resulting sets. We compare the cuts generated from such sets, which we call generalized or look-ahead intersection cuts, to cuts belonging to known families. In particular, we show that the new paradigm offers a way to generate in a non-recursive fashion deep cuts that can otherwise be generated only through several iterations of one of the standard procedures. Finally, we discuss implementation aspects and some preliminary computational experience.

Life sciences & healthcare

Mon.1.H 2033

Computational genomics

Organizer/Chair Alexander Schönhuth, Centrum Wiskunde & Informatica, Amsterdam · Invited Session

Hugues Richard, University Pierre and Marie Curie (with Manuel Holgrew, Marcel Schulz, David Weese)

Fiona: Automatic correction of sequencing errors in genome sequencing experiments

Next generation sequencing technologies can produce a large amount of artifacts. These artifacts are in general limited to one or a few positions, like base substitution or short insertions/deletions. In this context, automatic read error correction is an important step, as it allows to improve the performance of the downstream analysis tasks, such as genome assembly or SNP calling. However most of the proposed methods until now suffer from at least one of the following drawbacks: multiple parameters to set, large memory consumption, or no detection of indels. We propose a new standalone read error correction method, Fiona, based on suffix trees and which support all type of corrections for any next generation sequencing platform. Fiona is provided with an efficient implementation in the Seqan library with very small memory consumption that can be run on inexpensive hardware, but also supports multi-core parallelization if available. When assessing the accuracy of Fiona over an extensive set of conditions it always performed better than all other suffix tree based methods.

Marianna D'Addario, TU Dortmund (with Sven Rahmann)

DNA sequence design

One aim of DNA nanotechnology is to design oligonucleotides (oligos) for the self assembly of complex nanostructures, such as 4×4 tiles. The principle of DNA self assembly is the q -uniqueness or dissimilarity of oligos that ensures the formation of the desired nanostructure. To construct a set of q -unique oligos, three rules must be observed: First, every subsequence of length q (q -gram) occurs at most once. Second, if a q -gram occurs, then its reverse complement does not and vice versa. Third, self complementary q -grams do not occur at all. To generate a DNA sequence, a De Bruijn Graph over the alphabet $\{A, C, G, T\}$ can be used, where the edges are labeled with all q -grams and the nodes with all $(q - 1)$ -grams. The nodes represent the common overlaps between two successive q -grams. With an ILP it is possible to find a longest q -unique sequence (a longest path in the graph) by maximizing the number of chosen edges without violating the rules. This sequence can then be divided into several sequences to form a q -unique set of oligos. Different additional constraints can be specified.

Iman Hajirasouliha, Simon Fraser University (with Can Alkan, Ee. Eichler, F. Hach, F. Hormozdiari, Sc. Sahinalp)

Next-generation sequence characterization of complex genome structural variation.

Structural variation, in the broadest sense, is defined as the genomic changes among individuals that are not single nucleotide variants. Rapid computational methods are needed to comprehensively detect and characterize specific classes of structural variation using next-gen sequencing technology. We have developed a suite of combinatorial optimization algorithms focused on the characterization of structural variants that have been more difficult to assay different forms of genomic structural variation. I will present our algorithms and a summary of our results of 9 high-coverage human genomes regarding these particular classes of structural variation compared to other datasets. In particular, I will also summarize our read-depth analysis of 159 low-coverage human genomes for copy number variation of duplicated genes. The algorithms we have developed will provide a much needed step towards a highly reliable and comprehensive structural variation discovery framework, which, in turn will enable genomics researchers to better understand the variations in the genomes of newly sequenced human individuals including patient genomes.

Logistics, traffic, and transportation

Mon.1.H 0106

Facility location and p -median problems

Chair Sergio Garcia Quiles, Universidad Carlos III de Madrid

Sergio Garcia Quiles, Universidad Carlos III de Madrid (with Laureano Escudero)

On the p -median problem with uncertainty in the cost matrix

It has been shown that the deterministic p -median problem can be solved with just a column generation approach that is embedded in a branch-and-bound framework. Large-scale instances have been solved efficiently in a small computing time. However, quite often, the cost matrix coefficients are random variables. The aim of this paper is twofold. First, a model is presented to minimize the expected cost over a set of

scenarios of the outlook of the random variables while satisfying the first order stochastic dominance constraints (sdc) for a set of profiles in order to reduce the risk of the cost impact of the solution in non-wanted scenarios. And second, a scheme to obtain the solution of the stochastic p -median problem is developed by considering the splitting variable representation of the static Deterministic Equivalent Model (DEM) of the stochastic one. This scheme dualizes the non-anticipativity constraints and treats with a special procedure the sdc for each profile (since those constraints have variables from different scenarios). A computational experience is reported.

Vinicius Xavier, Federal University of Rio de Janeiro (with Felipe Franca, Priscila Lima, Adilson Xavier)
Solving the Fermat-Weber location problem by the hyperbolic smoothing approach

The Fermat-Weber problem considers the optimum location of a given number of facilities. The problem corresponds to the minimization of the sum of the euclidean distances of each city to its nearest facility weighted by relative importance of each one. The mathematical modeling of this problem leads to a min-sum-min formulation which in addition to its intrinsic bi-level nature, has the significant characteristic of being strongly non-differentiable and non-convex problem, with a large number of local minima. The hyperbolic smoothing strategy solves a sequence of low dimension differentiable unconstrained optimization sub-problems, which gradually approaches the original problem. The reliability and efficiency of the method are illustrated via a set of computational experiments by using traditional instances presented in the literature.

Halduñ Sural, METU Ankara (with Huseyin Guden)

The dynamic p -median problem with relocation

The dynamic location problem considers changes of demand amounts over the horizon and minimizes the location and service costs. In any period new facilities can be opened in addition to the operating facilities and some of the operating ones can be relocated or abolished. We develop exact and heuristic methods for solving the dynamic p -median problem. The former is a branch-and-price algorithm using the reduced size form of an integer programming formulation based on discretization of the number of different distances between facilities and demand points. The latter effort explores the dynamic structure of the problem to find upper bounds on the problem objective function. Our computational results are presented to assess the performance our methods on test instances derived from the p -median literature.

Logistics, traffic, and transportation

Mon.1.H 0111

Supply chain optimization

Organizer/Chair Edwin Romeijn, University of Michigan · Invited Session

Joseph Geunes, University of Florida (with Yiqiang Su)

Multi-period price promotions in a single-supplier, multi-retailer supply chain under asymmetric demand information

This paper considers a two-level supply chain in which a supplier serves a retail chain. We consider a two-stage Stackelberg game in which the supplier sets price discounts for each period of a finite planning horizon under uncertainty in retail-store demand. To stimulate sales, the supplier offers periodic off-invoice price discounts to the retail chain. Based on the price discounts offered, and after store demand uncertainty is resolved, the retail chain determines store order quantities in each period. The retailer may ship inventory between stores, a practice known as diverting. We demonstrate that, despite the resulting bull-whip effect and associated costs, a carefully designed price promotion scheme can improve the supplier's profit when compared to the case of everyday low pricing (EDLP). We model this problem as a stochastic bilevel optimization problem with a bilinear objective at each level and with linear constraints. We provide an exact solution method based on a Reformulation-Linearization Technique (RLT). In addition, we compare our solution approach with a widely used heuristic and another exact solution method from the literature in order to benchmark its quality.

Dolores Romero Morales, University of Oxford (with H. Edwin Romeijn, Wilco van den Heuvel)

A multi-objective economic lot-sizing problem with environmental considerations

In this talk we study a Multi-Objective Economic Lot-Sizing Problem. This Multi-Objective Economic Lot-Sizing Problem is a generalization of the classical Economic Lot-Sizing Problem, where we are concerned with both the lot-sizing costs, including production and inventory holding costs, as well as the production and inventory emission of pollution. With respect to the emissions, the planning horizon will be split into blocks of the same length (except for possibly the last one), and the total emission in each block will be minimized. This includes the case in which we are interesting in measuring the pollution in each of the planning periods, or across all periods, or more generally, across subsets

of periods. We assume fixed-charge production cost and emission functions, and linear inventory holding cost and emission functions. When more than one objective function is optimized, the Pareto efficient frontier is sought. In this talk, we show that the Pareto optimal problem is NP-complete. We then identify classes of problem instances for which Pareto optimal solutions can be obtained in polynomial time. We end with some results on the Pareto efficient frontier of the problem.

Zohar Strinka, University of Michigan (with H. Edwin Romeijn)

Approximation algorithms for risk-averse selective newsvendor problems

We consider a single-item single-period problem of a supplier who faces uncertain demands in a collection of markets and wishes to choose a subset of markets z whose demand to satisfy as well as a corresponding overall order quantity Q . The supplier faces costs associated with satisfying demands, overage and underage costs, and lost revenues in the markets whose demand is not selected. Moreover, the supplier optimizes a risk measure associated with those random costs. Finally, we assume that the joint distribution of all market demands and revenues is nonnegative with finite mean. We develop an approximation framework that, under certain conditions on the cost structure and risk measure, provides a solution whose objective function value is, with high probability, within a constant factor of the optimal value. This framework depends on two key techniques: (i) rounding the solution to a continuous relaxation of the problem, and (ii) sampling to approximate the true revenue and demand distribution. We provide explicit examples of some cost structures and risk measures for which the algorithm we develop is efficiently implementable.

Mixed-integer nonlinear programming

Mon.1.MA 005

Global mixed-integer nonlinear optimization I

Organizer/Chair Ignacio Grossmann, Carnegie Mellon University · Invited Session

Ignacio Grossmann, Carnegie Mellon University (with Juan Ruiz)

Using convex nonlinear relaxations in the global optimization of nonconvex generalized disjunctive programs

In this paper we address the global optimization of GDP problems that in addition to bilinear and concave terms, involve other terms such as linear fractional terms for which nonlinear convex relaxations have shown to provide rigorous convex envelopes that are magnitude much tighter than linear relaxations. The use of nonlinear convex relaxations leads to a nonlinear convex GDP which relaxation can be strengthened by using recently results from the recent work of Ruiz and Grossmann.

We first define the general nonconvex GDP problem that we aim at solving and review the use of the hull relaxation, the traditional method to find relaxations. Second, we show how we can strengthen the relaxation of the traditional approach by presenting a systematic procedure to generate a hierarchy of relaxations based on the application of basic steps to nonlinear convex sets in disjunctive programming. We outline a set of rules that avoids the exponential transformation to the Disjunctive Normal Form leading to a more efficient implementation of the method. Finally we assess the performance of the method by solving to global optimality engineering design test problems.

Miloš Bogataj, Faculty of Chemistry and Chemical Engineering, University of Maribor (with Zdravko Kravanja)

A multilevel approach to global optimization of MINLP problems

In this work, we present an approach for global optimization of non-convex mixed-integer nonlinear programs (MINLPs) containing bilinear and linear fractional terms. These terms are replaced by piecewise convex under-/overestimators defined over domains of one or both complicating variables. The domains are partitioned over at least two levels with increasing grid density. The densest grid is dense enough to ensure the gap between the upper and lower bound falls below the predefined convergence criterion. The derived multilevel convex MINLP is then solved using a modified outer approximation/equality relaxation (OA/ER) algorithm. The key idea of the approach is progressive tightening of convex relaxation, whilst keeping low combinatorial complexity of the convexified MINLP throughout the solution procedure. After each major OA/ER iteration, tighter under-/overestimators are activated, however, only over the domain partitions containing currently optimal solution. Hence, only the most promising alternatives are being explored from the start on. The multilevel approach was tested on illustrative examples to show its advantage over a single level approach.

Tapio Westerlund, Åbo Akademi University (with Andreas Lundell)

A reformulation framework for global optimization

In some previous papers we have published results connected to an optimization framework for solving non-convex mixed integer nonlinear programming problems, including signomial functions. In the framework the global optimal solution of such non-convex problems

can be obtained by solving a converging sequence of convex relaxed MINLP problems. The relaxed convex problems are obtained by replacing the non-convex constraint functions with convex underestimators. The signomial functions are first convexified by single-variable power and exponential transformations. The non-convexities are then moved to the transformations. However, when replacing the transformations with piecewise linear approximations the problem will be both convexified and relaxed.

The scope of this paper is to show how any twice-differentiable function can be handled in an extended version of the global optimization framework. For C^2 -functions it is shown how a spline version of the so-called α BB-underestimator can be applied in a slightly similar way as the approach utilized for signomial functions. It is, further, shown how this underestimator can easily be integrated in the actual reformulation framework.

Multi-objective optimization

Mon.1.H 1029

Linear and integer multiobjective optimization

Chair Matthias Ehrgott, The University of Auckland

Markku Kallio, Aalto University School of Economics (with Merja Halme)

Reference point method for multi-criteria optimization with integer variables

An interactive approach for multi-objective optimization with integer variables is introduced. In each iteration, the decision maker (DM) is asked to give a reference point (new aspiration levels). Subsequent Pareto optimal point is the reference point projected into the set of feasible objective vectors using a suitable scalarizing function. Thereby, the procedure solves a sequence of optimization problems with integer variables. In such process, the DM provides preference information via pair-wise comparisons of Pareto-optimal points identified. Using such preference information and assuming a quasi-concave utility function of the DM we restrict the set of admissible objective vectors by excluding subsets, which cannot improve over the solutions already found. Infeasibility in an iteration implies convergence and the best Pareto point found is an optimal solution. We also propose a procedure to test whether or not a solution is a supported Pareto point (optimal under some linear value function). Our reference point optimization procedure runs in AMPL/MOSEK. Numerical tests with multi criteria facility location models and knapsack problems indicate reasonably fast convergence

Matthias Ehrgott, The University of Auckland (with Maryam Hassanasab, Andrea Raith)

A multi-objective linear programming approach to data envelopment analysis

Data envelopment analysis (DEA) is a very popular parameter free method for performance measurement of decision making units. Based on linear programming (LP), DEA is closely related to multi-objective linear programming (MOLP) in the sense that efficient decision making units represent efficient solutions of some MOLP. We exploit this relationship and apply the primal and dual variants of Benson's outer approximation algorithm for MOLP as presented in Ehrgott, Löhne and Shao (2012) in order to solve DEA problems. We show that when applied to DEA many of the LPs that need to be solved in these algorithms reduce to trivial problems of finding the minima of finite sets. The geometric duality of multi-objective linear programming furthermore allows us to identify all efficient DMUs without solving a linear programme for every DMU using the dual outer approximation algorithm. Moreover the primal outer approximation algorithm directly finds all hyperplanes defining the efficient frontier of the production possibility set. We demonstrate the efficiency of our algorithm on a number of standard DEA reference problems.

Mohammad Ali Yaghoobi, Shahid Bahonar University of Kerman (with Alireza Dehmiry)

Using ball center of a polytope to solve a multiobjective linear programming problem

Recently, ball center of a polytope as the center of a largest ball inside the polytope is applied to solve a single objective linear programming problem. The current research aims to develop an algorithm for solving a multiobjective linear programming problem based on approximating ball center of some polytopes obtained from the feasible region. In fact, the proposed algorithm asks a weight vector from the decision maker and then tries to solve the problem iteratively. It is proved that the algorithm converges to an epsilon efficient solution after a finite number of iterations. Moreover, the well performance of it in comparison with the well known weighted sum method is discussed. Furthermore, numerical examples and a simulation study are used to illustrate the validity and strengths of the recommended algorithm.

Nonlinear programming

Mon.1.H 0107

Methods for nonlinear optimization I

Chair Jean-Pierre Dussault, Université de Sherbrooke

Xin-Wei Liu, Hebei University of Technology

How does the linear independence assumption affect algorithms of nonlinear constrained optimization

The terminology on the global convergence of algorithms for constrained optimization is first defined. Some recent progress in nonlinear equality constrained optimization is then surveyed. The Steihaug's conjugate gradient method is applied to the linearized constraint residual minimization problem and its convergence result is proved. The discussions are then extended to the optimization with inequality constraints. The local results demonstrate that the algorithm can be of superlinear convergence even though the gradients of constraints are not linearly independent at the solution.

Mario Mommer, IWR/Heidelberg University (with Hans-Georg Bock, Johannes Schlöder, Andreas Sommer)

A nonlinear preconditioner for experimental design problems

Optimal experimental design is the task of finding, given an experimental budget, a setup that reduces as much as possible the uncertainty in the estimates of a set of parameters associated with a model. These optimization problems are difficult to solve numerically, in particular when they are large. Beyond the technical challenges inherent to the formulation of the problem itself, which is based on the optimality conditions of a nonlinear regression problem, it is common to observe slow convergence of the sequential quadratic programming (SQP) methods that are used for its solution. We show that the minima of experimental design problem can have large absolute condition numbers under generic conditions. We develop a nonlinear preconditioner that addresses this issue, and show that its use leads to a drastic reduction in the number of needed SQP iterations. Our results suggest a role for absolute condition numbers in the preasymptotic convergence behavior of SQP methods.

Jean-Pierre Dussault, Université de Sherbrooke

The behaviour of numerical algorithms without constraint qualifications

We consider inequality constrained mathematical optimisation problems. Under suitable constraint qualifications, at x^* a minimiser of such a problem there exists a KKT multiplier set $\Lambda(x^*)$ so that for any $\lambda \in \Lambda(x^*)$ x^* satisfies the so called KKT necessary conditions. Usually, stronger assumptions are used to study the behaviour of numerical algorithms in the neighbourhood of a solution, such as LICQ and the strict complementarity condition. Recent works weakened such assumptions and studied the behaviour of algorithm close to degenerate solutions. We explore here the case where no CQ is satisfied, so that $\Lambda(x^*)$ may be the empty set. In such a case, clearly, primal-dual algorithmic forms are ill-defined. Based on our recent high order path following strategy, we obtain a useful algorithmic framework. This context provides a case where Shamanskii-like high order variants are useless while genuine high order extrapolations yield a solution.

Nonlinear programming

Mon.1.H 0110

Nonlinear optimization I

Organizers/Chairs Frank E. Curtis, Lehigh University; Daniel Robinson, Johns Hopkins University - Invited Session

Eckstein Jonathan, Rutgers University (with Yao Wang)

Alternating direction methods and relative error criteria for augmented Lagrangians

We examine the computational behavior of a number of variations on the alternating direction method of multipliers (ADMM) for convex optimization, focusing largely on lasso problems, whose structure is well-suited to the method. In particular, we computationally compare the classical ADMM to minimizing the augmented Lagrangian essentially exactly by alternating minimization before each multiplier update, and to approximate versions of this strategy using the recent augmented Lagrangian relative error criterion of Eckstein and Silva.

Gillian Chin, Northwestern University (with Richard Byrd, Jorge Nocedal, Figen Oztoprak)

A family of second order methods for L1 convex optimization

We describe and analyze a family of second order methods for minimizing an objective that is composed of a smooth convex function and an L1 regularization term. The algorithms in this family are categorized as two phase methods, differing with respect to the active manifold identification phase and the second order subspace step. We will show how to endow these algorithms with convergence guarantees and as well,

Nonsmooth optimization

propose a new algorithm, contrasting this method with established approaches. We report numerical results on large scale machine learning applications.

Stefan Solntsev, Northwestern University (with Richard Byrd, Jorge Nocedal)

Dynamic batch methods for L1 regularized problems and constrained optimization

A methodology for using dynamic sample sizes in batch-type optimization methods is proposed. Motivated by machine learning applications, dynamic batching can successfully be applied to smooth convex constrained problems as well as non-smooth L1-regularized problems. By dynamically changing the batch size, the algorithm is able to keep overall costs low. The use of a batch approach allows the algorithm to exploit parallelism.

Nonlinear programming

Mon.1.H 0112

Algorithms for optimal control I

Chair Carsten Gräser, Freie Universität Berlin / MATHEON

Dennis Janka, Heidelberg University (with Hans-Georg Bock, Stefan Körkel, Sebastian Sager)

Separable formulations of optimum experimental design problems

We consider optimal control problems coming from nonlinear optimum experimental design. These problems are non-standard in the sense that the objective function is not of Bolza type. In a straightforward direct solution approach one discretizes the controls and regards the states as dependent variables. However, this often leads to poor convergence properties of the resulting NLP. We propose a reformulation of the problem to a standard optimal control problem by introducing additional variables. It is then possible to attack this problem with direct state-of-the-art methods for optimal control with better convergence properties, e.g., multiple shooting. The reformulation gives rise to a highly structured NLP due to the multiple shooting discretization as well as due to the peculiarities of the optimum experimental design problem. We highlight some of these structures in the constraints, the objective function, and the Hessian matrix of the Lagrangian, and present ways to exploit them leading to efficient SQP methods tailored to optimum experimental design problems. Numerical results are presented comparing the new separable formulations to an existing implementation.

Kathrin Hatz, Otto-von-Guericke-Universität Magdeburg (with Hans-Georg Bock, Johannes Schlöder)

Hierarchical dynamic optimization - Numerical methods and computational results for estimating parameters in optimal control problems

We are interested in numerical methods for hierarchical dynamic optimization problems with a least-squares objective on the upper level and an optimal control problem (OCP) with mixed path-control constraints on the lower level. The OCP can be considered as a model (a so-called optimal control model) that describes optimal processes in nature, such as the gait of cerebral palsy patients. The optimal control model includes unknown parameters that have to be determined from measurements. We present an efficient direct all-at once approach for solving this class of problems. The main idea is to discretize the infinite dimensional bilevel problem, replace the lower level nonlinear program (NLP) by its first order necessary conditions (KKT conditions), and solve the resulting complex NLP with a tailored sequential quadratic programming (SQP) method. The performance of our method is discussed and compared with the one of alternative approaches. Furthermore, we present an optimal control model for a cerebral palsy patient which has been identified from real-world motion capture data that has been provided by the Motion Laboratory of the University Hospital Heidelberg.

Carsten Gräser, Freie Universität Berlin / MATHEON

Truncated nonsmooth newton multigrid methods for nonsmooth minimization

The combination of well-known primal-dual active-set methods for quadratic obstacle problems with linear multigrid solvers leads to algorithms that sometimes converge very fast, but fail to converge in general. In contrast nonlinear multilevel relaxation converges globally but exhibits suboptimal convergence speed and complexity.

Combining nonlinear relaxation and active-set ideas we derive the globally convergent "truncated nonsmooth Newton multigrid" (TNNMG) method. While its complexity is comparable to linear multigrid its convergences in general much faster than multilevel relaxation. Combined with nested iteration it turns out to be essentially as fast as multigrid for related linear problems. This the method relies on minimization the generalization to more other nonquadratic, nonsmooth energies is straight forward.

Mon.1.H 1012

Iterative methods for variational analysis

Organizer/Chair Alain Pietrus, Université des Antilles et de la Guyane · Invited Session

Celia Jean-Alexis, Université des Antilles et de la Guyane (with Michel Geoffroy, Alain Pietrus)

The second order generalized derivative and generalized equations

We consider a generalized equation of the form $0 \in f(x) + G(x)$ where $f: \mathbb{R}^n \rightarrow \mathbb{R}^n$ is a $C^{1,1}$ function such that its Fréchet-derivative f' is subanalytic and $G: \mathbb{R}^n \rightarrow 2^{\mathbb{R}^n}$ is a set-valued map metrically regular. First of all, we present some iterative methods introduced for solving this equation and then we state our main result. In fact, we propose a method using the second order generalized derivative and we show existence and convergence of a sequence defined by this method.

Robert Baier, University of Bayreuth

Set-valued Newton's method for computing convex invariant sets

A new realization of Newton's method for "smooth" set-valued fixed-point problems is presented. For a dynamical system $x_{k+1} = g(x_k)$ a convex invariant set $X \subset \mathbb{R}^n$ has to be determined with $g(X) = X$.

This fixed-point problem is transformed to a zero-finding problem in the Banach space of directed sets for which Newton's method can be formulated. The cone of convex, compact subsets of \mathbb{R}^n can be embedded into this Banach space such that usual set arithmetics are extended and a visualization of differences of embedded convex compact sets as usually nonconvex subsets of \mathbb{R}^n is available.

Important assumptions are the existence of a set of convex subsets such that their image under g remains convex and the existence of a differentiable extension of g to directed sets. The visualization of an embedded fixed set for the transformed problem is a convex invariant set for the original problem.

First examples illustrate that the convergence assumptions can be verified and local quadratic convergence even to unstable convex invariant sets is observed in contrary to fixed set iterations. Further extensions of this approach are indicated.

Elza Farkhi, Tel-Aviv University (with Robert Baier, Vera Roshchina)

The directed subdifferential and applications

The directed subdifferential of quasidifferentiable functions is introduced as the difference of two convex subdifferentials embedded in the Banach space of directed sets. Preserving the most important properties of the quasidifferential, such as exact calculus rules, the directed subdifferential lacks major drawbacks of the quasidifferential: non-uniqueness and growing in size of the two convex sets representing the quasidifferential after applying calculus rules. Its visualization, the Rubinov subdifferential, is a non-empty, generally non-convex set in \mathbb{R}^n . Calculus rules for the directed subdifferentials are derived. Important properties as well as necessary and sufficient optimality conditions for the directed subdifferential are obtained. The Rubinov subdifferential is compared with other well-known subdifferentials.

Optimization in energy systems

Mon.1.MA 549

Optimization models to manage risk and uncertainty in power systems operations

Organizers/Chairs Raphael Chabar, PSR; Luiz Barroso, PSR · Invited Session

Alexandre Street, Pontifical Catholic University of Rio de Janeiro (PUC-Rio) (with Arroyo Jose, Alexandre Moreira)

Energy and reserve scheduling under a joint GT $n - K$ security criterion: An adjustable robust optimization approach

This presentation shows a new approach for energy and reserve scheduling in electricity markets under a general $n - K$ security criterion. It extends previous robust optimization based works that only considered generation faults to consider a joint GT criterion. A Benders decomposition is applied in combination with a set of valid constraints based on a single-bus reduction of the problem. Such constraints provide a tighter formulation for the master problem resulting in significant improvements in the method computational burden.

Jinye Zhao, ISO New England

Adaptive robust optimization for the security constrained unit commitment problem

Unit commitment, one of the most critical tasks in electric power system operations, faces new challenges as the supply and demand uncertainty increases dramatically due to the integration of variable generation resources. To meet these challenges, we propose a two-stage adaptive robust unit commitment model and a practical solution method. We present a numerical study on the real-world large scale power system operated by the ISO New England. Computational results

demonstrate the economic and operational advantages of our model over the traditional reserve adjustment approach.

Anthony Papavasiliou, University of California at Berkeley (with Shmuel Oren)

Applying high performance computing to multi area stochastic unit commitment for high wind penetration

We use a two-stage stochastic programming formulation in order to schedule locational generation reserves that hedge power system operations against the uncertainty of renewable power supply. We present a parallel implementation of a Lagrangian relaxation algorithm for solving the stochastic unit commitment problem. The model we present addresses the uncertainty of wind power supply, the possibility of generator and transmission line outages and transmission constraints on the flow of power over the network. We present a scenario selection algorithm for representing uncertainty in terms of a moderate number of appropriately weighted scenarios and use a high performance computing cluster in order to validate the quality of our scenario selection algorithm. We compare the performance of our approach to $N-1$ reliable unit commitment. We examine the dependence of the Lagrangian duality gap on the number of scenarios in the model and relate our results to theoretical bounds provided in the literature. We finally report results regarding speedup and efficiency.

Optimization in energy systems

Mon.1.MA 550

Unit commitment and inventory problems

Chair Tim Schulze, The University of Edinburgh

Ali Koc, IBM TJ Watson Research Center (with Jayant Kalagnanam)

Parallel branch-cut-price for solving multistage stochastic unit commitment problems

Unit commitment (UC) lies in the heart of future smart grid. Independent system operators and utilities aim to solve various forms of the problem that handle such contemporary concepts as renewable generation, energy storage, power purchase agreements, future power markets, demand response, etc. These concepts induce various forms of uncertainty into the problem. We use multistage stochastic programming framework to incorporate these uncertainties, and present a parallel decomposition algorithm based on a branch-cut-price framework. We bring together several advancements in the UC literature, stochastic programming, mixed integer programming, large-scale optimization, and parallel computing. We develop a new weighting scheme and a lower bounding method to improve the decomposition algorithm, and a constructive heuristic method to restore near-optimal solutions. The serial algorithm solves problem instances as efficient as highly sophisticated commercial solvers, and the parallel algorithm solves large-scale nonlinear stochastic UC problem instances with up to 3000 generators, 24 hours, and 200 scenarios on a 32-processor cluster, obtaining almost linear speedups.

Kin Keung Lai, City University of Hong Kong (with Qiang Wang, Qian Zhang)

A stochastic approach to power inventory optimization

Rooted in the airline industry, inventory management systems have been applied for 40 years since the first paper by Beckmann. This involves application of information systems and pricing strategies to allocate the right capacity to the right customer at the right price at the right time. Also there are some salient differences between airlines and power plants. For example: (i) electric power has to be generated, transmitted and consumed at the same time; and (ii) safety of power grid is also an important factor to be considered, implying more strict requirements for cancellations, no-shows and overbooking problems. Also, unlike the airline industry, orders for electricity power usually last for a period of time such as one day, one week, one month and even one year, and the price varies with quantity and time periods. Advance bookings are encouraged even one day or even half-an-hour in advance in order to guarantee safety and efficiency of the power grid and the power plant. This study is developed on the basis of power plants facing stochastic demand with varied prices. A network optimization mode is proposed for power plant inventory management under an uncertain environment.

Tim Schulze, The University of Edinburgh (with Andreas Grothey, Kenneth McKinnon)

Decomposition methods for stochastic unit commitment

In recent years the expansion of energy supplies from volatile renewable sources has triggered an increased interest in stochastic optimization models for generation unit commitment. Several studies have modelled the problem as a stochastic mixed-integer (piecewise linear or convex quadratic) multi-stage problem. Solving this problem directly is computationally intractable for large instances and many alternative approaches have been proposed. However, few of them exploit the structure of the multi-stage formulation. In this talk we outline how decomposition and coordination methods can be applied to exploit the struc-

ture of the underlying scenario tree. It has been shown that progressive hedging can yield good solutions for this problem, and we give a short review of our findings from applying it. However, this method is not guaranteed to converge for mixed-integer problems. Therefore the focus of the talk is on a branch & price framework which guarantees convergence. Numerical results are given to illustrate the behaviour of the method.

PDE-constrained opt. & multi-level/multi-grid meth.

Mon.1.MA 415

Applications of PDE-constrained optimization

Organizer/Chair Michael Ulbrich, Technische Universität München · Invited Session

Reue Pinnau, TU Kaiserslautern

Exploiting model hierarchies in space mapping optimization

The solution of optimization problems in industry often requires information on the adjoint variables for very complex model equations. Typically, there is a whole hierarchy of models available which allows to balance the computational costs and the exactness of the model. We exploit these hierarchies in combination with space mapping techniques to speed up the convergence of optimization algorithms. The use of surrogate models yields finally a suboptimal design or control, which is typically near to the optimal design. In this talk we present three applications where this approach proved to be very successful. We will cover questions from semiconductor design, the control of particles in fluids and shape optimization for filters.

Michael Ulbrich, Technische Universität München (with Christian Böhm)

An adaptive semismooth Newton-CG method for constrained parameter identification in seismic tomography

Seismic tomography infers the material properties of the Earth based on seismograms. This can be stated as an optimization problem that minimizes the misfit between observed and simulated seismograms.

We present a semismooth Newton-CG method for full-waveform seismic inversion with box constraints on the material parameters. It uses a Moreau-Yosida regularization and a trust-region globalization. The matrix-free implementation relies on adjoint-based gradient and Hessian-vector computations and a PCG method. The state equation is a coupled system of the elastic and acoustic wave equations. Our MPI-parallelized solver uses a high order continuous Galerkin method and an explicit Newmark time stepping scheme.

We address ill-posedness by a regularization and, in addition, by inverting sequentially for increasing frequencies. Thereby, the parameter grid is adaptively refined using goal-oriented a posteriori error estimates.

Numerical results are shown for the application of our method to a dataset of marine geophysical exploration in the North Sea.

Robust optimization

Mon.1.H 3503

Extensions of robust optimization models

Chair Frank Pfeuffer, Zuse-Institut Berlin

Michael Todd, Cornell University (with Martina Gancarova)

A robust robust (sic) optimization result

We study the loss in objective value obtained when an inaccurate objective is optimized instead of the true one, and show that "on average", the loss incurred is very small, for arbitrary compact feasible regions.

Frank Pfeuffer, Zuse-Institut Berlin (with Utz-Uwe Haus)

An extension of the controlled robustness model of Bertsimas and Sim

Realistic data in optimization models is often subject to uncertainty. Robust optimization models take such data uncertainty into account. Bertsimas and Sim proposed a robust model which deals with data uncertainty while allowing to control the amount of robustness in the problem by bounding the number of simultaneously uncertain coefficients. They showed that under this model robust min-cost-flow problems are solved by binary search using an oracle for min-cost-flow problems.

We extend this model by allowing more general means of imposing control on the amount of robustness via polyhedral control sets, which contain the model of Bertsimas and Sim as a special case. Under our model, robust min-cost-flow problems are solved by a subgradient approach using an oracle for min-cost-flow problems. Applying our approach to the restrictive control set of Bertsimas and Sim reduces the number of oracle calls needed by their approach by half.

Sparse optimization & compressed sensing

Mon.1.H 1028

New models and algorithms in sparse optimization

Organizer/Chair Benjamin Recht, University of Wisconsin-Madison · Invited Session

Nicolas Boumal, UC Louvain (with Pierre-Antoine Absil, Amit Singer)

Riemannian algorithms and estimation bounds for synchronization of rotations

We estimate unknown rotation matrices R_i in $SO(n)$ from a set of measurements of relative rotations $R_i R_j^T$. Each measurement is either slightly noisy, or an outlier bearing no information. We study the case where most measurements are outliers. We propose a Maximum Likelihood Estimator (MLE) approach, explicitly acknowledging outliers in the noise model.

The MLE maximizes the log-likelihood function over the parameter space. That space is a product of rotation groups, possibly quotiented to account for invariance under a common rotation of the estimators.

To compute the MLE, we use Riemannian trust-region methods to maximize the log-likelihood function over the parameter space. That space is a matrix manifold, hence tools and analyses from (Absil et al., *Optimization Algorithms on Matrix Manifolds*, Princeton Univ. Press, 2008) apply gracefully.

We derive Riemannian Cramer-Rao bounds for synchronization, valid for a broad class of problem dimensions and noise distributions. These bounds admit a simple expression in terms of an information-weighted Laplacian of the measurement graph. Numerical tests suggest the MLE is asymptotically efficient in many cases.

Mark Davenport, Georgia Institute of Technology (with Michael Wakin)

A simple framework for analog compressive sensing

Compressive sensing (CS) has recently emerged as a framework for efficiently capturing signals that are sparse or compressible in an appropriate basis. While often motivated as an alternative to Nyquist-rate sampling, there remains a gap between the discrete, finite-dimensional CS framework and the problem of acquiring a continuous-time signal. In this talk, I will describe a new approach to bridging this gap by exploiting the Discrete Prolate Spheroidal Sequences (DPSS's), a collection of functions that trace back to the seminal work by Slepian, Landau, and Pollack on the effects of time-limiting and bandlimiting operations. DPSS's form a highly efficient basis for sampled bandlimited functions; by modulating and merging DPSS bases, we obtain a dictionary that offers high-quality sparse approximations for most sampled multiband signals. This multiband modulated DPSS dictionary can be readily incorporated into the CS framework. I will provide theoretical guarantees and practical insight into the use of this dictionary for recovery of sampled multiband signals from compressive measurements.

Benjamin Recht, University of Wisconsin-Madison (with Badri Bhaskar, Parikshit Shah, Gongguo Tang)

Atomic norm denoising with applications to spectrum estimation and system identification

One of the most common goals of data analysis is to reject noise by leveraging the latent structure present in the true signal. This talk will propose a general approach to such *denoising* problems by regularizing data fidelity with a penalty called the atomic norm. Atomic norm denoising is posed as a convex optimization problem and has generic, mean-squared-error guarantees. For sparse signals, atomic norm denoising is equivalent to soft-thresholding, but our techniques can be applied to estimate a variety of other objects and structures beyond sparse signals and images.

To demonstrate the wide applicability of atomic norm denoising, I will specialize the abstract formulation to two applications of practical interest. First, I will present a convex approach to superresolution, estimating the frequencies and phases of a mixture of complex exponentials. I will then apply the framework to identify linear dynamical systems from noisy, incomplete measurements. In both cases, atomic norm denoising efficiently achieves comparable or better error to existing heuristics without a priori knowledge of system parameters such as model order.

Stochastic optimization

Mon.1.MA 141

Advances in stochastic optimization

Organizer/Chair David Brown, Duke University · Invited Session

David Brown, Duke University

Optimal sequential exploration: Bandits, clairvoyants, and wildcats

This paper was motivated by the problem of developing an optimal strategy for exploring a large oil and gas field in the North Sea. Where should we drill first? Where do we drill next? The problem resembles a classical multiarmed bandit problem, but probabilistic dependence plays a key role: outcomes at drilled sites reveal information

about neighboring targets. Good exploration strategies will take advantage of this information as it is revealed. We develop heuristic policies for sequential exploration problems and complement these heuristics with upper bounds on the performance of an optimal policy. We begin by grouping the targets into clusters of manageable size. The heuristics are derived from a model that treats these clusters as independent. The upper bounds are given by assuming each cluster has perfect information about the results from all other clusters. The analysis relies heavily on results for bandit superprocesses, a generalization of the classical multiarmed bandit problem. We evaluate the heuristics and bounds using Monte Carlo simulation and, in our problem, we find that the heuristic policies are nearly optimal.

Ciamac Moallemi, Columbia University (with Vijay Desai, Vivek Farias)

Pathwise optimization for linear convex systems

We describe the pathwise optimization method, an approach for obtaining lower bounds on the minimal cost of a general class of linear-convex control problems. Our method delivers tight bounds by tractably identifying an optimal information relaxation penalty function. We demonstrate our method on a high-dimensional financial application. We provide theory to show that the bounds generated by our method are provably tighter than those of some other commonly used approaches.

Constantine Caramanis, The University of Texas at Austin

Optimization at all levels: Probabilistic Envelope Constraints

In optimization under uncertainty, we often seek to provide solutions that provide guaranteed performance at least $p\%$ of the time. But what happens the other $(1-p)\%$ of the time? Current methodology fails to provide any constraints on these bad events: $(1-p)\%$ of the time, all bets are off. In this talk we provide a computationally tractable framework to design optimization solutions that have performance guarantees at all levels of uncertainty realizations. We call these probabilistic envelope constraints, and, as we show, they have a surprising connection to an extension of robust optimization.

Stochastic optimization

Mon.1.MA 144

Optimization of physical systems under uncertainty

Organizer/Chair Mihai Anitescu, Argonne National Laboratory · Invited Session

Victor Zavala, Argonne National Laboratory (with Mihai Anitescu, John Birge)

Stochastic optimization: Impacts on electricity markets and operations

In this talk, we discuss impacts of stochastic optimization on market clearing procedures and power plant operations. In particular, we demonstrate that stochastic optimization leads to more consistent prices that maximize social welfare, reduce variance of spot prices, and diversify generation. In addition, we demonstrate how stochastic optimization leads to large amounts of power can be saved in large base-load plants in the presence of water constraints.

Jim Luedtke, University of Wisconsin-Madison (with Yongjia Song)

Branch-and-cut approaches for chance-constrained formulations of reliable network design problems

We study the design of reliably connected networks. Given a graph with arcs that may fail at random, the goal is to select a minimum cost set of arcs such that a path between nodes s and t exists with high probability. We model this problem as a chance-constrained stochastic integer program, and present two solution approaches. The first approach is based on a formulation that uses binary variables to determine if an $s-t$ path exists in each arc failure scenario. We present a branch-and-cut decomposition algorithm to solve this formulation, based on inequalities derived from individual scenario graph cuts. The second approach uses an alternative formulation based on probabilistic $s-t$ cuts, which is an extension of $s-t$ cuts to graphs with random arc failures. Probabilistic $s-t$ cut inequalities define the feasible region and can be separated efficiently at integer solutions, allowing this formulation to be solved by a branch-and-cut algorithm. Computational results will be presented that demonstrate that the approaches can solve large instances. We also show how our results can be applied to more general connectivity requirements.

Bernardo Pagnoncelli, Universidad Adolfo Ibáñez (with Adriana Piazzola)

The optimal harvesting problem under risk aversion

I will present a model for the exploitation of a one species forest plantation when timber price is governed by a stochastic process. The problem is stated as a risk averse stochastic dynamic programming, with the conditional value-at-risk (CVaR) as a risk measure. Timber price is uncertain and two important cases are considered: geometric Brownian motion and a mean-reverting (Ornstein-Uhlenbeck) process.

In both cases the problem is solved for every initial condition and the best policy is obtained endogenously, that is, without imposing any ad hoc restrictions such as maximum sustained yield or convergence to a predefined final state. I will compare the results with the risk neutral framework and discuss the differences between the two cases. Finally I will show how to generalize the results to any coherent risk measure that is affine on the current price.

Stochastic optimization

Mon.1.MA 376

Decisions policies and estimation techniques in a stochastic environment

Organizer/Chair Fabian Bastin, University of Montreal · Invited Session

Atwin Haensel, VU University Amsterdam (with Marco Laumanns)

A SP approach for decision-dependent uncertainty in production planning under non-compliance risk

Governmental regulation pressure on production quality and standards is increasing in many areas, especially in the chemical, food and pharmaceutical industries. Therefore, a production plan needs to consider the risks of failing the quality inspection by the authority agency. Inspection realizations are clearly dependent on the previous production planning decisions. Normally stochastic programs assume the random process to be independent of the optimization decision. This dependency increases the complexity of the underlying problem significantly. The uncertain inspection realizations are modelled by scenarios, which are generated according given product-site hazards. We propose a general scenario based stochastic programming approach and start initially with a risk-neutral model maximizing the expected revenue. The model is extended to account for more risk-averse attitudes of the decision maker by introducing probabilistic constraints. The main focus is on a direct CVaR (conditional value-at-risk) optimization formulation.

Fabian Bastin, University of Montreal (with Anh Tien Mai, Michel Toulouse)

On the combination of Hessian approximations for data estimation

Data estimation is increasingly more computing intensive as more data becomes available, and as it is used with always more complex models. Typical estimation procedures have however very specific structures, even when the models are nonlinear, and we aim to exploit them, but this may compromise convergence when we get close to the solution. In particular, we revisit optimization techniques relying on multiple Hessian approximation update schemes, with a specific focus on maximum likelihood techniques involving expensive objective functions. Such functions can for instance be constructed as Monte Carlo samples on some population and some inner expectations, as considered in fields like discrete choice theory. Using a trust-region approach, we show that combinations of standard secant updates (SR1 and BFGS) and statistical approximations (here the BHHH update), can dramatically decrease the time required to converge to the solution, and that it is possible to build strategies aimed to minimize the number of objective function evaluations using a retrospective approach. Numerical experiments on real data are presented in order to demonstrate the approach potential.

Xinan Yang, Lancaster University (with Andreas Grothey)

Approximate dynamic programming with Bézier curves/surfaces for top-percentile traffic routing

Multi-homing is used by Internet Service Providers to connect to the Internet via different network providers. This study develops a routing strategy under multi-homing in the case where network providers charge ISPs according to top-percentile pricing (i.e. based on the θ -th highest volume of traffic). We call this problem the Top-percentile Traffic Routing Problem (TpTRP).

To overcome the curse of dimensionality in Stochastic Dynamic Programming, in previous work we have suggested to use Approximate Dynamic Programming (ADP) to construct value function approximations, which allow us to work in continuous state space. The resulting ADP model provides well performing routing policies for medium sized instances. In this work we extend the ADP model, by using Bézier Curves/Surfaces to obtain continuous-time approximations of the time-dependent ADP parameters. This modification reduces the number of regression parameters to estimate and thus accelerates the efficiency of parameter training in the solution of the ADP model, which makes realistically sized TpTRP instances tractable. We argue that our routing strategy is near optimal by giving bounds.

Telecommunications & networks

Mon.1.H 3002

Optical access networks

Organizer/Chair Andreas Bley, TU Berlin · Invited Session

Cédric Hervet, Orange Labs / CNAM (with Matthieu Chardy, Marie-Christine Costa, Alain Faye, Stanislas Francfort)

Robust optimization of optical fiber access networks deployments

Due to the recent increase in bandwidth requirements, telecommunication operators have to support it with the deployment of optical fiber networks through Fiber-To-The-Home Gigabit Passive Optical Network technology (FTTH GPON). One great challenge, in a deregulated context, is to design this network while not knowing who and where the future subscribers will be. We focus on the problem of the robust optical fiber network deployment under demand uncertainty. A two-stage robust optimization model is proposed for this problem, as well as two robust solution methods extending classical results from Ben-Tal et al. and Babonneau et al. in order to be compliant with our uncertainty set.

Maria João Lopes, University Institute of Lisbon (ISCTE-IUL) and CIO (with Amaro de Sousa, Luis Gouveia)

Modelling the minimum cost PON access network design problem

A PON is an optical access network connecting a Central Office to a set of terminals using optical splitters, installed on intermediate nodes, and optical fibres connecting all elements. In the network design problem, terminals are clustered in a minimum number of PONs and each PON has a maximum capacity in number of terminals. For each PON, we have to decide where to install splitters and how to connect all elements through optical fibres. In intermediate nodes, optical splitters of different PONs can co-exist. There are costs associated with intermediate nodes, splitter types and fibre connections. We define the minimum cost design problem in the context of densely populated urban areas, proposing different ILP formulations and valid inequalities. We address this problem in the general context where the number of splitting stages (and the splitting ratio on each stage) is an outcome of the optimization problem. Therefore, previous works became particular cases of this general network design problem. We present computational results discussing the trade-off between the linear relaxation bounds and the runtime to achieve integer optimal solutions of the different models.

Olaf Maurer, TU Berlin (with Andreas Bley, Ivana Ljubic)

Lagrangian approaches to a two-level FTTX network design problem

We consider the design of a passive optical telecommunication access network, where clients have to be connected to an intermediate level of distribution points (DPs) and further on to some central offices (COs). Each client demands a given number of connections to its CO. Passive optical splitters installed at the DPs allow several connections to share a single common connection between the DP and the CO. The objective is composed of fixed-charge costs for the use of facilities and hardware and linear costs which depend on the edge utilisation. We present two Lagrangean decomposition approaches that were improved with additional cuts and heuristics. The subproblems are solved using MILP techniques. We report computational results and compare the efficiency of the Lagrangian approach to the direct approach via an integrated MILP model.

Variational analysis

Mon.1.H 2035

Nonsmooth phenomena in optimal control

Organizer/Chair Roland Herzog, TU Chemnitz · Invited Session

Christian Meyer, TU Dortmund

Boundary control of the obstacle problem

The talk deals with optimal control problems governed by the obstacle problem, where the control is given by Neumann data. Several stationarity concepts for the problem under consideration and additionally second-order sufficient conditions are presented.

Matthias Gerdts, Universität der Bundeswehr

Globalized semi-smooth Newton methods in optimal control problems with DAEs

This paper addresses the numerical solution of optimal control problems subject to differential-algebraic equations and mixed control-state constraints by semi-smooth Newton methods. A particular focus is on globalization techniques for semi-smooth Newton methods and on regularization and smoothing techniques for the Fischer-Burmeister function. An open problem for the convergence analysis remains the construction of a smoothing operator for the Fischer-Burmeister function. Numerical experiments on various problems without smoothing operator however suggest that the methods work well in practice and a

superlinear convergence rate and mesh independence can be observed numerically.

Frank Schmidt, TU Chemnitz (with Roland Herzog)

Properties of the optimal value function and application to worst-case robust optimal control problems

Sufficient conditions ensuring weak lower semi-continuity of the optimal value function are presented. To this end, refined inner semi-continuity properties of set-valued maps are introduced which meet the needs of the weak topology in Banach spaces. The results are applied to prove the existence of solutions in various worst-case robust optimal control problems governed by semilinear elliptic partial differential equations.

Variational analysis

Mon.1.H 2051

Equilibrium problems and related topics

Organizer/Chair Alfredo Iusem, Instituto de Matemática Pura e Aplicada · Invited Session

Orizon Ferreira, Federal University of Goiás (with Roberto Silva)

Local convergence of Newton's method under majorant condition in Riemannian manifolds

A local convergence analysis of Newton's method for finding a singularity of a differentiable vector field defined on a complete Riemannian manifold, based on majorant principle, is presented in this paper. This analysis provides a clear relationship between the majorant function, which relaxes the Lipschitz continuity of the derivative, and the vector field under consideration. It also allows us to obtain the optimal convergence radius, the biggest range for the uniqueness of the solution, and to unify some previous unrelated results.

Susana Scheimberg, UFRJ-Universidade Federal do Rio de Janeiro (with Paulo Santos)

A reflection-projection method for equilibrium problems

We consider an implementable algorithm for solving nonsmooth equilibrium problems in finite-dimensional spaces. The algorithm combines the strategy of generating a feasible point, by using reflections related to hyperplanes, and the projected-type subgradient method where the projection is done onto a suitable half-space. The algorithm has a low computational cost per iteration. Computational experience is reported and comparative analysis with other algorithms is also given.

Luis Drummond, UFRJ - Universidade Federal do Rio de Janeiro (with E. Fukuda)

New strategies for vector optimization problems

Under partial orders derived from arbitrary closed convex pointed cones with nonempty interior, we propose extensions of scalar optimization procedures to the vector setting. For constrained vector-valued optimization, we seek efficient/weakly efficient points by adapting classical real-valued strategies. Assuming reasonable hypotheses, we establish some convergence results to optimal points.

Approximation & online algorithms

Mon.2.H 3010

Real-time scheduling

Organizer/Chair Sanjoy Baruah, University of North Carolina at Chapel Hill · Invited Session

Martin Niemeier, TU Berlin (with Andreas Wiese)

Scheduling with an orthogonal resource constraint

We address a type of scheduling problems that arises in highly parallelized environments like modern multi-core CPU/GPU computer architectures. Here simultaneously active jobs share a common limited resource, e.g., a memory cache. The scheduler must ensure that the demand for the common resource never exceeds the available capacity. This introduces an orthogonal constraint. Almost any scheduling problem can be made "resource aware" by adding this constraint. Here we focus on two classes of scheduling problems. On the one hand, we study "classical" makespan minimization problems such as scheduling on identical machines. On the other hand, we study real-time scheduling problems [e.g., partitioned scheduling of synchronous/sporadic tasks on parallel multi-processors].

We present approximation algorithms (either in terms of makespan minimization or machine-speedup minimization) for several variants of the problem.

Suzanne van der Ster, Vrije Universiteit Amsterdam (with Sanjoy Baruah, Vincenzo Bonifaci, Gianlorenzo D'angelo, Haohan Li, Alberto Marchetti-Spaccamela, Leen Stougie)

Mixed-criticality scheduling of sporadic task systems on a single machine

We consider scheduling an implicit-deadline task system on a single machine in a mixed-criticality (MC) setting. MC systems arise when

multiple functionalities are scheduled upon a shared computing platform. This can force tasks of different importance (i.e., criticality) to share a processor.

Each task generates a (possibly infinite) string of jobs, released with an interarrival time bounded from below by a task-dependent period. Each job has a relative deadline equal to the length of its period.

In an MC setting, each task has multiple levels of worst-case execution times and its own criticality level. By executing the tasks, we learn what level the system is in, which may change over time. When the system is in level ℓ , all jobs of tasks of level $\geq \ell$ should be scheduled for their level- ℓ execution time, to meet their deadline.

We give an algorithm for scheduling an MC task system, called EDF-VD (Earliest Deadline First with Virtual Deadlines). We give sufficient conditions to check feasibility for K levels. We show that if a 2-level task system is schedulable on a unit-speed processor, it is correctly scheduled by EDF-VD on a processor of speed $4/3$.

Jian-Jia Chen, KIT (with Samarjit Chakraborty)

Resource augmentation in real-time systems

Timing satisfaction is an important property for maintaining the stability or correctness of many real-time embedded systems, especially for avionic or automotive applications. For decades, schedulability of real-time systems has been extensively studied, from periodic tasks, to sporadic tasks, and even to tasks with irregular arrival curves. A task set is guaranteed to be schedulable if it passes the correct schedulability tests. However, the main issue for such an approach is to answer what can be guaranteed when a task set does not pass the schedulability test. For such cases, the resource augmentation factor provides a nice feature to ensure the schedulability by augmenting the resources, e.g., by speeding-up, adding more processors, etc. This talk will focus on the recent researches on resource augmentation with respect to speeding-up and allocating more processors in real-time systems for sporadic real-time tasks, from uniprocessor systems to multiprocessor systems. The analysis for resource augmentation upper bound and lower bound will be presented.

Combinatorial optimization

Mon.2.H 3004

Combinatorial optimization in chip design II

Organizer/Chair Ulrich Brenner, University of Bonn · Invited Session

Ulrike Suhl, Research Institute for Discrete Mathematics University of Bonn (with Stephan Held)

Lagrangian relaxation and quadratic minimum cost flows for gate sizing

One of the key problems during the physical design of a computer chip is to choose a physical realization (gate size) for each gate/transistor on the chip from a discrete set. Available sizes for a gate differ in their power and area usage, and influence the time it takes electrical signals to traverse the chip.

We present a Gate Sizing algorithm based on Lagrangian Relaxation minimizing overall circuit power, while fulfilling constraints imposed on the speed of electrical signals.

We restrict gate sizes to the discrete sets available in practice, and solve a discretized primal problem to avoid a rounding step in the end. Instances are modified appropriately to guarantee the existence of a finite dual solution.

Lagrange Multiplier have to be projected to the flow space, which can be formulated as a Quadratic Minimum Cost Flow Problem.

Constraints on the area usage of gates in specified regions on the chip can be incorporated directly into the framework, and we show convergence for the continuous case.

Christoph Bartoschek, University of Bonn (with Stephan Held, Jens Vygen)

Fast buffering of repeater trees

The optimization of electrical interconnections is a critical task in the design of modern VLSI chips. A popular approach is to divide the problem into a Steiner tree computation and a buffering step that inserts repeaters for strengthening the electrical signals. For buffering it is common to use a dynamic program that is also the basis for a FPTAS to find low-power delay-optimal solutions. However, there are several drawbacks. Firstly, potential buffer positions have to be chosen upfront. Secondly, the underlying embedded tree topology is fixed. Finally, dynamic programming causes high running times. We present a fast algorithm for the buffering problem. It precomputes technology dependent optimal spacings, so that long distances can be buffered quickly using the precomputed data. Merging branches at steiner points is done by a short enumeration of possible solutions. We modify the original Steiner topology if this reduces the number of inserted repeaters, which sometimes would only be required for preserving Boolean parity. We present

computational results demonstrating the high and often superior quality of our buffering solutions.

Stephan Held, University of Bonn

Delay bounded Steiner trees and time-cost tradeoffs for faster chips

We will present combinatorial optimization algorithms that focus on maximizing the clock frequency of modern microprocessors. One central problem is the construction of Steiner trees with delay constraints. They are used for optimizing electrical interconnections and symmetric Boolean functions. We provide a bicriteria approximation algorithm for tree topologies with node delays in addition to length dependent delays. This is done by generalizing light approximate shortest path trees.

For finding globally optimal solutions, many resource critical problems such as threshold voltage of transistors and layer assignment of interconnect wires can be modeled as time-cost tradeoff problems. We will present a new method based on rounding the dual of Minimum-Cost Flows.

Finally, we will demonstrate how the presented algorithms are employed for increasing the clock frequency by 18% of an upcoming microprocessor.

Combinatorial optimization

Mon.2.H 3005

Structural graph theory and methods

Organizer/Chair Paul Wollan, University of Rome - Invited Session

Sang-Il Oum, KAIST

Vertex-minors and pivot-minors of graphs

We will survey vertex- and pivot-minor relations of graphs which are defined in terms of local complementation and pivot operations, respectively, on graphs. Many theorems on graph minors can be extended to graph vertex- or pivot-minors. We will discuss various known aspects and then talk about partial results towards some conjectures generalizing some of the deepest theorems in structural graph theory including the graph minor theorem of Robertson and Seymour.

Gwenaél Joret, Université Libre de Bruxelles (with Samuel Fiorini, David Wood)

Excluded forest minors and the Erdős-Pósa Property

A classical result of Robertson and Seymour states that the set of graphs containing a fixed planar graph H as a minor has the so-called Erdős-Pósa property; namely, there exists a function f depending only on H such that, for every graph G and every integer $k \in \mathbb{N}$, either G has k vertex-disjoint subgraphs each containing H as a minor, or there exists a subset X of vertices of G with $|X| \leq f(k)$ such that $G - X$ has no H -minor. While the best function f currently known is super-exponential in k , a $O(k \log k)$ bound is known in the special case where H is a forest. This is a consequence of a theorem of Bienstock, Robertson, Seymour, and Thomas on the pathwidth of graphs with an excluded forest-minor.

In this talk I will sketch a proof that the function f can be taken to be linear when H is a forest. This is best possible in the sense that no linear bound exists if H has a cycle.

Serguei Norine, McGill University (with Robin Thomas, Hein van der Holst)

Pairs of disjoint cycles

We will describe a polynomial-time algorithm which determines whether an input graph contains a pair of disjoint cycles with the given property. In particular, it allows one to test whether a graph has two disjoint odd cycles, whether it has two disjoint cycles, one non-zero modulo 3 and the other non-zero modulo 5, whether a graph embedded in a surface has two disjoint homologically non-trivial cycles, and whether a given embedding of a graph in 3-space is linkless.

The algorithm is based on an efficient characterization of the span of a certain collection of matrices indexed by pairs of disjoint cycles, extending a theorem of van der Holst and a characterization of linklessly embeddable graphs due to Robertson, Seymour and Thomas.

Combinatorial optimization

Mon.2.H 3008

Discrete structures and algorithms I

Organizer/Chair Satoru Fujishige, Kyoto University - Invited Session

Shuji Kijima, Graduate School of Information Science and Electrical Engineering, Kyushu University

Efficient randomized rounding in permutahedron

Permutahedron P_n is a polyhedron in the n dimensional space defined by the convex hull of all permutations vectors $x(\pi) = (\pi(1), \pi(2), \dots, \pi(n)) \in \mathbb{R}^n$. In this talk, we are concerned with randomized rounding in permutahedron; given a point $p \in P_n$, output a permutation vector $X(\pi)$ with a probability satisfying that $E[X] =$

$\sum_{\pi \in S_n} \Pr[X = x(\pi)]x(\pi) = p$. It is well known that P_n is a base polyhedron of a submodular function, more precisely $P_n = \{x \mid \sum_{i \in I} x_i \leq \sum_{j=1}^{|I|} (n+1-j) \text{ for any } I \subset [n], \text{ and } \sum_{i \in [n]} x_i = n(n+1)/2\}$. In this talk, we present an algorithm for randomized rounding in permutahedron, with $O(n \log n)$ time using $O(n)$ space. We also explain an extension to a base polyhedron of an arbitrary cardinality based submodular function.

Júlia Pap, Eötvös Loránd University (with András Frank, Tamás Király, David Pritchard)

Characterizing and recognizing generalized polymatroids

Generalized polymatroids are a family of polyhedra with several nice properties and applications. A main tool used widely in the literature is that generalized polymatroids can be described by a linear system whose dual can be uncrossed: there is an optimal dual solution with laminar support. We make this notion of "total dual laminarity" explicit and show that the polyhedra described by such systems are always generalized polymatroids. We also show that for a full-dimensional generalized polymatroid every describing system is totally dual laminar. Using these we give a polynomial-time algorithm to check whether a given linear program defines a generalized polymatroid, and whether it is integral if so. Additionally, whereas it is known that the intersection of two integral generalized polymatroids is integral, we show that no larger class of polyhedra satisfies this property.

Jens Massberg, University of Ulm (with Satoru Fujishige)

Dual consistency and cardinality constrained polytopes

We introduce a concept of dual consistency of systems of linear inequalities with full generality. We show that a cardinality constrained polytope is represented by a certain system of linear inequalities if and only if the systems of linear inequalities associated with the cardinalities are dual consistent. Typical dual consistent systems of inequalities are those which describe polymatroids, generalized polymatroids, and dual greedy polyhedra with certain choice functions. We show that the systems of inequalities for cardinality-constrained ordinary bipartite matching polytopes are not dual consistent in general, and give additional inequalities to make them dual consistent. Moreover, we show that ordinary systems of inequalities for the cardinality-constrained (poly)matroid intersection are not dual consistent, which disproves a conjecture of Murras, Spiegelberg, and Stephan about a linear representation of the cardinality-constrained polymatroid intersection.

Combinatorial optimization

Mon.2.H 3012

Scheduling I

Chair George Steiner, McMaster University

Thomas Rieger, Technische Universität Braunschweig (with Ronny Hansmann, Uwe Zimmermann)

Two variants of flexible job shop scheduling with blockages

Motivated by an application in rail car maintenance, we discuss makespan-minimization for two variants of flexible job shop scheduling with work centers (FJc). In contrast to standard FJc in these variants a work center (rail track) consists of a linearly ordered set of machines with restricted accessibility. In particular, a busy machine blocks both the access to and the exit from all succeeding machines of a work center. The two considered variants only differ in the implication of the latter restricting requirement. If a succeeding machine is blocked when it completes a job then this job is either allowed to wait on its machine (until the exit is free again) or not.

In particular, we present the computational complexity and solution methods (heuristic and exact) and introduce a mixed integer linear programming model for both variants. Our exact methods are based on a dedicated branch-and-bound-implementation using bounds generated from certain longest paths.

Finally, we present some computational results for several data sets, discuss the solution quality of both FJc-variants and compare our results to results obtained using the commercial solvers CPLEX and Gurobi.

Leen Stougie, VU University & CWI Amsterdam (with Frans Schalenkamp, Rene Sitters, Suzanne van der Ster, Anke van Zuylen)

Scheduling with job-splitting and fixed setup

We consider a scheduling problem with a fixed setup time and job-splitting. Jobs can be preempted and machines can work on the same job simultaneously. We encountered this problem in studying disaster relief operations. We consider minimisation of total completion time. The version with preemption and fixed setup time s is still solved by the Shortest Processing Time first rule (SPT), in which the option of preemption is not used. The situation with job-splitting is much less clear. If s is very large, then splitting becomes too expensive and the problem is solved by SPT again. If s is very small (say 0), then each job is split over all machines and the jobs are scheduled in SPT order. To find out

Combinatorial optimization

where to start splitting jobs and over how many machines appears to be a non-trivial problem.

We will present a polynomial time algorithm for the case in which there are 2 machines exploiting the structure of optimal solutions. Some of the crucial properties of optimal solutions already fail to hold on 3 machines. This leaves the complexity of the problem for more than 2 machines open.

George Steiner, McMaster University

Scheduling and the traveling salesman problem on permuted monge matrices

A large variety of scheduling problems has been shown to be solvable as special cases of the Traveling Salesman Problem (TSP) on permuted Monge matrices. Although the TSP on permuted Monge matrices is known to be strongly NP-hard, polynomial-time solutions exist for many of the special cases generated by the scheduling problems. Furthermore, a simple subtour-patching heuristic is asymptotically optimal for the TSP on permuted Monge matrices under some mild technical conditions.

Combinatorial optimization

Mon.2.H 3013

Recoverable robust combinatorial optimization

Organizer/Chair Arie Koster, RWTH Aachen University · Invited Session

Christina Büsing, RWTH Aachen

k -distance recoverable robustness

Recoverable Robustness (RR) is a method to deal with uncertainties in optimization problems extending the classical concept of robustness by allowing limited recovery actions after all data is revealed. In this talk I will present a special case of RR where the recovery actions are limited by changing at most k elements of the previous fixed solution and apply this method to various combinatorial optimization problems. For the shortest path problem, we will see that small changes in the problem setting, e.g., choosing simple s, t -paths at the beginning instead of any s, t -path, strongly influences the complexity status and combinatorial structures of the optimal solutions. I will conclude the talk with an overview of current results on cutting planes for the recoverable robust knapsack polytope and an application to the train classification problem.

Arie Koster, RWTH Aachen University (with Christina Büsing, Manuel Kutschka)

The recoverable robust knapsack problem

In this talk, we consider the knapsack problem with uncertain item weights. In contrast to the classical robust setting, a limited recovery action is allowed, i.e., up to k items may be removed when the actual weights are known. This problem is motivated by the assignment of traffic nodes to antennas in wireless network planning and the bandwidth packing problem from telecommunication.

We study two scenarios to represent the uncertainty. First, a finite set of realizations is discussed. Second, the uncertainty is modelled by the approach of Bertsimas and Sim (2003,2004) limiting the number of deviations from nominal values by a parameter Γ . For both cases, we present the results of a polyhedral study, generalizing the well-known cover inequalities. Computational experiments conclude the presentation.

Marjan van den Akker, Utrecht University (with Paul Bouman, Han Hoogeveen, Denise Tonissen)

Column generation for the demand robust shortest path problem

We study the demand robust shortest path problem. Initially we are given the source but the sink is uncertain. We have to buy a set of arcs containing a path from the source to the sink. Arcs can be bought when the sink is still unknown, or, at a higher price, after the sink has been revealed.

Our approach is based on *recoverable robustness*, i.e. we make an initial plan which is guaranteed to be recoverable to a feasible solution by a fast and simple recovery algorithm. We apply the technique of column generation to find solutions to our recoverable robust optimization problem. In an earlier paper, we have identified two types of column generation approaches: separate recovery and combined recovery, and have tested these for a recoverable robust knapsack problem. For the demand robust shortest path problem, we present an algorithm based on combined recovery decomposition and show computational results.

Mon.2.H 3021

Scheduling algorithms II

Organizer/Chair Vincenzo Bonifaci, IASI-CNR, Italy · Invited Session

Cyriel Ruten, Maastricht University (with Alberto Marchetti-Spaccamela, Suzanne van der Ster, Andreas Wiese)

Scheduling sporadic tasks on unrelated parallel machines

In modern hardware architectures it has become a very common feature to contain several types of processors with possibly completely different characteristics. In (real-time) scheduling, this feature is modeled by assuming the machines of a system to be unrelated. We study the problem of assigning sporadic tasks to unrelated machines such that the tasks on each machine can be feasibly scheduled.

We develop a polynomial-time algorithm which approximates the problem with a constant speedup factor of $11 + 4\sqrt{3} \approx 17.9$ when the number of machines is arbitrary. Further, we show that any polynomial-time algorithm needs a speedup factor of at least 2, unless $P = NP$. Also, if the number of machines is constant, we approximate the problem to a factor of $1 + \epsilon$. Key to these results are two new relaxations of the demand bound function which yields a sufficient and necessary condition for a task system on a single machine to be feasible.

Andreas Wiese, Università di Roma 'La Sapienza' (with Elisabeth Günther, Olaf Maurer, Nicole Megow)

A new approach to online scheduling: Approximating the optimal competitive ratio

We propose a new approach to competitive analysis in online scheduling by introducing the concept of online approximation schemes. Such a scheme algorithmically constructs an online algorithm with a competitive ratio arbitrarily close to the best possible competitive ratio for any online algorithm. Also, it provides algorithmic means to compute the actual value of the best possible competitive ratio up to an arbitrary accuracy.

We study the problem of scheduling jobs online to minimize the weighted sum of completion times on parallel, related, and unrelated machines. By constructing online approximation schemes we derive both deterministic and randomized algorithms which are almost best possible among all online algorithms of the respective settings. We also generalize our techniques to arbitrary monomial cost functions and apply them to the makespan objective. Our method relies on an abstract characterization of online algorithms combined with various simplifications and transformations.

Nicole Megow, Technische Universität Berlin (with Julian Mestre)

Nearly optimal universal solutions for knapsack and sequencing on an unreliable machine

Dual-value sequencing with an unknown covering or packing constraint appears as a core subproblem, e.g., when scheduling on an unreliable machine or when determining a universal knapsack solution. A sequence is called α -robust when, for any possible constraint, the maximal or minimal prefix of the sequence that satisfies the constraint is at most a factor α from an optimal packing or covering. It is known that the covering problem always admits a 4-robust solution, and there are instances for which this factor is tight. For the packing variant no such constant robustness factor is possible.

In this work we aim for more meaningful, instance-dependent robustness guarantees. We present an algorithm that constructs for each instance a solution with a robustness factor arbitrarily close to optimal. This implies nearly optimal solutions for universal knapsack and scheduling on an unreliable machine. The crucial ingredient is an approximate feasibility test for dual-value sequencing with a given target function. This result may be of independent interest. We show that deciding exact feasibility is strongly NP-hard, and thus, our test is best possible, unless $P=NP$.

Complementarity & variational inequalities

Mon.2.MA 041

Game theoretic analysis and optimization for resource allocation in communication systems

Organizer/Chair Zhi-Quan (Tom) Luo, University of Minnesota · Invited Session

Slawomir Stanczak, Fraunhofer HHI and TU Berlin

Progress and challenges in decentralized resource allocation optimization

This talk presents an overview of algorithmic solutions to optimization problems that naturally appear in the radio resource management for wireless networks. A wireless network is modeled as a weighted graph, in which pairs of nodes form communication links, while the weighted edges capture the interference effects between different links. The focus is on utility maximization approaches. We will show how

primal-dual methods can provide quadratic convergence, while still allowing for efficient implementation in decentralized wireless networks. Given the limited and costly nature of wireless resources, decentralized algorithms are required to minimize the control message overhead for each iteration step. Therefore we present a distributed handshake scheme based on the use of so-called adjoint network to efficiently estimate iteration updates from some locally measurable quantities. Due to estimation errors and other distorting factors, the proposed algorithm has to be analyzed in a more general context of stochastic approximation.

Zhi-Quan (Tom) Luo, University of Minnesota (with Mingyi Hong, Razaviyayn Meisam, Sun Ruoyu)

Linear precoder optimization and base station selection for heterogeneous networks

Consider the problem of weighted sum rate maximization in a MIMO interference communication network. We propose to jointly optimize the users' linear precoders as well as their base station (BS) associations. This approach enables the users to avoid congested BSs and can improve system performance as well as user fairness. In this paper we first show that this joint optimization problem is NP-hard and thus is difficult to solve to global optimality. We also identify a special case (single antenna case) where the joint maximization of the minimum rate problem is solvable via an appropriate weighted bipartite matching for base station assignment and then a simple linear program for power allocation. To find a locally optimal solution, we formulate the problem as a noncooperative game in which the users and the BSs act as players who autonomously optimize their own utility functions. We then develop an algorithm that allows the players to distributedly reach the Nash Equilibrium (NE) of the game. Moreover, we introduce a set of utility functions for the players and show that every NE of the resulting game is a stationary solution of the weighted sum rate maximization problem.

Gesualdo Scutari, State University of New York at Buffalo (with Francisco Facchinei, Jong-Shi Pang)

Monotone communication games

In recent years, there has been a growing interest in the use of noncooperative games to model and solve many resource allocation problems in communications and networking, wherein the interaction among several agents is by no means negligible and centralized approaches are not suitable. In this talk we present a mathematical treatment of (generalized) Nash equilibrium (NE) problems based on the variational inequality approach. Our emphasis is on the design of distributed algorithms using best-response iterations along with their convergence properties. The proposed framework has many desirable new features: i) it can be applied to (monotone) games having no specific structure; ii) the algorithms proposed for computing a NE converge under mild conditions that do not imply the uniqueness of the equilibrium; and iii) in the presence of multiple NE, one can control the quality of the computed solution by guaranteeing convergence to the "best" NE, according to some prescribed criterion, while keeping the distributed implementation of the algorithm. These are new features enlarge considerably the applicability and flexibility of game-theoretic models in wireless distributed networks.

Complementarity & variational inequalities

Mon.2.MA 313

Optimization and equilibrium problems I

Organizers/Chairs Christian Kanzow, University of Würzburg; Michael Ulbrich, Technische Universität München · Invited Session

Oliver Stein, Karlsruhe Institute of Technology (with Nadja Harms, Christian Kanzow)

On differentiability properties of player convex generalized Nash equilibrium problems

Any smooth generalized Nash equilibrium problem allows a reformulation as a single constrained minimization problem with possibly nonsmooth objective function. Under the assumption of player convexity, we study smoothness properties of this objective function and, by using several results from parametric optimization, we show that, except for special cases, all locally minimal points of the reformulation are differentiability points. This justifies a numerical approach which basically ignores the possible nondifferentiabilitys.

Alexandra Schwartz, University of Würzburg (with Jörg Franke, Christian Kanzow, Wolfgang Leininger)

Biased lottery versus all-pay auction contests: A revenue dominance theorem

We allow a contest organizer to bias a contest in a discriminatory way, that is, he can favor specific contestants through the choice of the contest success function in order to maximize the total equilibrium effort. Revenue enhancement through biasing is analyzed and compared for the two predominant contest regimes: all-pay auctions and lottery contests. In order to determine the optimally biased all-pay auction or lottery contest, the organizer has to solve a mathematical program with equilibrium constraints. We derive the optimally biased lottery contest

analytically. But although this optimal lottery has a few interesting properties, it turns out that the optimally biased lottery contest will always be dominated by an appropriately biased all-pay auction.

Michael Ferris, University of Wisconsin

Stochastic variational inequalities and MOPEC

We describe some recent extensions of the extended mathematical programming (EMP) framework that enable the modeling of stochastic variational inequalities and link these to the notion of multiple optimization problems with equilibrium constraints (MOPEC). We show how to incorporate stochastic information into these systems, including notions of hedging and dynamics, and give examples of their use and their possible extensions to hierarchical modeling. We contrast these approaches to existing modeling formats such as complementarity problems and mathematical programs with equilibrium constraints, and show how this relates to decentralized operations. We demonstrate this mechanism in the context of energy and environmental planning problems, specifically for capacity expansion, hydro operation, water pricing and load shedding.

Conic programming

Mon.2.H 2036

Algorithms for matrix optimization problems

Chair Yu Xia, Lakehead University

Qingna Li, AMSS, Chinese Academy of Sciences (with Houduo Qi)

Sequential semismooth Newton method for nearest low-rank correlation matrix problem

Rank constrained matrix optimization problems have been receiving great interest in the past few years due to the applications in various fields. One of such problems is the nearest low-rank correlation matrix problem, arising from finance. In this talk, we propose the sequential semismooth Newton method to solve it. We analyze the connections between the proposed method and some other methods. Potential improvement of the method is also discussed.

Chengjing Wang, Southwest Jiaotong University (with Defeng Sun, Kim-Chuan Toh)

On how to solve large scale matrix log-determinant optimization problems

We propose a Newton-CG primal proximal point algorithm (PPA) and a Newton-CG primal augmented Lagrangian method (ALM) for solving large scale nonlinear semidefinite programming problems whose objective functions are a sum of a log-determinant term with a linear function and a sum of a log-determinant term with a convex quadratic function, respectively. Our algorithms employ the essential ideas of the PPA, the ALM, the Newton method, and the preconditioned conjugate gradient (CG) solver. We demonstrate that our algorithms perform favorably compared to existing state-of-the-art algorithms and are much preferred when a high quality solution is required for problems with many equality constraints.

Yu Xia, Lakehead University

Gradient methods for a general least squares problem

We consider a constrained least squares problem over cones. We show how to adapt Nesterov's fast gradient methods to the problem efficiently. Numerical examples will be provided.

Conic programming

Mon.2.H 2038

Nonlinear semidefinite programs and copositive programs

Organizer/Chair Florian Jarre, Universität Düsseldorf · Invited Session

Michal Kocvara, University of Birmingham (with Jan Fiala, Michael Stingl)

Introducing PENLAB, a Matlab code for nonlinear conic optimization

We will introduce a new code PENLAB, an open Matlab implementation and extension of our older PENNON. PENLAB can solve problems of nonconvex nonlinear optimization with standard (vector) variables and constraints, as well as matrix variables and constraints. We will demonstrate its functionality using several nonlinear semidefinite examples.

Mirjam Dür, University of Trier (with Willemieke van Vliet)

Remarks on copositive plus matrices and the copositive plus completion problem

A matrix A is called copositive plus if it is copositive and if for $x \geq 0$, $x^T A x = 0$ implies $Ax = 0$. These matrices play a role in linear complementarity problems (LCPs), since it is well known that Lemke's algorithm can solve LCPs when the matrix involved is copositive plus.

In this talk, we study two issues: first, we discuss properties of the cone of copositive plus matrices. In particular, we formulate an analogous result to the well-known fact that any copositive matrix of order up

to four can be represented as a sum of a positive semidefinite and an entrywise nonnegative matrix.

The second problem we are interested in is the copositive plus completion problem: Given a partial matrix, i.e., a matrix where some entries are unspecified, can this partial matrix be completed to a copositive plus matrix by assigning values to the unspecified entries? We answer this question both for the setting where diagonal entries are unspecified, and for the case of unspecified non-diagonal entries.

Peter Dickinson, Johann Bernoulli Institute, University of Groningen (with Kurt Anstreicher, Samuel Burer, Luuk Gijben)

Considering the complexity of complete positivity using the Ellipsoid method

Copositive programming has become a useful tool in dealing with all sorts of optimisation problems. It has however been shown by Murty and Kabadi [Some NP-complete problems in quadratic and nonlinear programming, *Mathematical Programming*, 39, no.2:117–129, 1987] that the strong membership problem for the copositive cone, that is deciding whether or not a given matrix is in the copositive cone, is a co-NP-complete problem. The dual cone to the copositive cone is called the completely positive cone, and, because of this result on the copositive cone, it has widely been assumed that the strong membership problem for this cone would be an NP-complete problem. The proof to this has however been lacking. In order to show that this is indeed true we would need to show that the problem is both an NP-hard problem and a problem in NP. In this talk we use the Ellipsoid Method to show that this is indeed an NP-hard problem and that the weak membership problem for the completely positive cone is in NP (where we use a natural extension of the definition of NP for weak membership problems). It is left as an open question as to whether the strong membership problem itself is in NP.

Constraint programming

Mon.2.H 3003A

Improved representations for constraint programming

Organizers/Chairs Jean-Charles Régin, University Nice-Sophia Antipolis; Michel Rueher, University of Nice Sophia Antipolis · Invited Session

Willem-Jan van Hoeve, Carnegie Mellon University (with David Bergman, Andre Cire, John Hooker)

Applying decision diagrams to constraint optimization problems

Binary Decision Diagrams (BDDs) can be used to compactly represent all solutions to a discrete combinatorial problem. As BDDs may have exponential size, we propose to utilize *limited-size* BDDs as relaxations and restrictions of the problem. We will show how limited-size BDDs can improve constraint propagation as well as strengthen the optimization reasoning.

Michel Rueher, University of Nice Sophia Antipolis

Using IIS for error localization

Modern model-checkers are often very efficient for generating counterexamples, i.e., to compute input data violating a given property or a post-condition. However, the associated execution traces are often lengthy and difficult to understand. Hence, the localization of the portions of code that contain errors is therefore often very expensive, even for experienced programmers. Recently, Griesmayer et al proposed to encode a trace of a program and the post-condition as a failing Boolean formula F . They use MAX-SAT to compute the maximum number of clauses that can be satisfied in F and output the complement as a potential cause of the errors. We propose here to improve their approach and to use IIS (irreducible infeasibility set) for the linear constraint subsystems. The advantage is that linear constraints provide a much more richer and concise model for numeric programs than Boolean formula.

Charlotte Truchet, LINA, Université de Nantes (with Frédéric Benhamou, Marie Pelteau)

Octagonal domains for constraint programming

Continuous Constraint Programming relies on interval representations of the variables domains. Filtering and solution set approximations are based on Cartesian products of intervals, called boxes. We propose to improve the Cartesian representation precision by introducing an n -ary octagonal representation of the domains in order to improve the propagation accuracy. The principles of constraint solving remain the same: reduce the domains by applying constraint propagators (filtering), by computing fixpoints of these operators (propagation) and by splitting the domains to search the solution space. Nevertheless, each of these steps is redesigned so as to take the new domains into account. Our contributions are the following: first, we show how to transform the initial constraint problem into an semantically equivalent problem on octagonal domains. Second, we define a specific local consistency, oct-consistency, and propose a propagation algorithm, built on top of any continuous filtering method. Third, we propose a split algorithm and a notion of precision adapted to the octagonal case. Practical experiments

show that the octagonal domains perform well on the Coconut benchmark.

Finance & economics

Mon.2.H 3027

New developments in computational finance

Organizer/Chair Thomas Coleman, University of Waterloo · Invited Session

Thomas Coleman, University of Waterloo (with Xi Chen)

On the use of automatic differentiation to efficiently determine first and second derivatives in financial applications

Many applications in finance require the efficient computation of the first derivatives (i.e., "Greeks") and sometimes 2nd derivatives of pricing functions of financial instruments. This is particularly true in the context of portfolio optimization and hedging methodologies. Efficient and accurate derivative computations are required. If the target instruments are simple, e.g., vanilla instruments, then this task is simple: indeed, analytic formulae exist and can be readily used. However, explicit formulae for more complex models are unavailable and the accurate and efficient calculation of derivatives is not a trivial matter. Examples include models that require a Monte Carlo procedure, securities priced by the Libor market model, the Libor swap market model, and the copula model. A straightforward application of automatic differentiation (AD) is exorbitantly expensive; however, a structured application of AD can be very efficient (and highly accurate). In this talk we illustrate how these popular pricing models exhibit structure that can be exploited, to achieve significant efficiency gains, in the application of AD to compute 1st and 2nd derivatives of these models.

Raquel Fonseca, Faculty of Sciences - University of Lisbon (with Berç Rustem)

Robust value-at-risk with linear policies

We compute the robust value-at-risk in the context of a multistage international portfolio optimization problem. Decisions at each time period are modeled as linearly dependent on past returns. As both the currency and the local asset returns are accounted for, the original model is non-linear and non-convex. With the aid of robust optimization techniques, however, we develop a tractable semidefinite programming formulation of our model, where the uncertain returns are contained in an ellipsoidal uncertainty set. The worst case value-at-risk is minimized over all possible probability distributions with the same first two order moments. We additionally show the close relationship between the minimization of the worst case value-at-risk and robust optimization, and the conditions under which the two problems are equivalent. Numerical results with simulated and real market data demonstrate the potential gains from considering a dynamic multiperiod setting relative to a single stage approach.

Christoph Reisinger, University of Oxford

The effect of the payoff on the penalty approximation of American options

This talk combines various methods of analysis to draw a comprehensive picture of penalty approximations to the value, hedge ratio, and optimal exercise strategy of American options. While convergence of the penalised PDE solution for sufficiently smooth obstacles is well established in the literature, sharp rates of convergence and particularly the effect of gradient discontinuities (i.e. the omni-present 'kinks' in option payoffs) on this rate have not been fully analysed so far. We use matched asymptotic expansions to characterise the boundary layers between exercise and hold regions, and to compute first order corrections for representative payoffs on a single asset following a diffusion or jump-diffusion model. Furthermore, we demonstrate how the viscosity theory framework can be applied to this setting to derive upper and lower bounds on the value. In a small extension, we derive weak convergence rates also for option sensitivities for convex payoffs under jump-diffusion models. Finally, we outline applications of the results, including accuracy improvements by extrapolation.

Game theory

Mon.2.MA 043

Large games and networks: Control and approachability

Organizer/Chair Dario Bauso, Università di Palermo · Invited Session

Giacomo Como, Lund University (with Daron Acemoglu, Munther Dahleh, Emilio Frazzoli, Ketan Savla)

Stability analysis of transportation networks with multiscale driver decisions

Stability of Wardrop equilibria is analyzed for dynamical transportation networks in which the drivers' route choices are influenced by information at multiple temporal and spatial scales. The considered model

involves a continuum of drivers commuting between a common origin/destination pair in an acyclic transportation network. The drivers' route choices are affected by their, relatively infrequent, perturbed best responses to global information about the current network congestion levels, as well as their instantaneous local observation of the immediate surroundings as they transit through the network. A novel model is proposed for the drivers' route choice behavior, exhibiting local consistency with their preference toward globally less congested paths as well as myopic decisions in favor of locally less congested paths. The main result shows that, if the frequency of updates of path preferences is sufficiently small as compared to the frequency of the traffic flow dynamics, then the state of the transportation network ultimately approaches a neighborhood of the Wardrop equilibrium. The presented results may be read as a further evidence in support of Wardrop's postulate of equilibrium.

Dario Bauso, Università di Palermo (with Giuseppe Notarstefano, Raffaele Pesenti)

Time-averaged consensus and distributed approachability in large multi-agent networks

We consider a doubly (over time and space) distributed averaging algorithm in a large multi-agent network. At every iteration, each single agent first computes a weighted average of its own time-averaged estimate and those of his neighbors and then generates a new estimate in order to drive the time-averaged estimate towards a pre-assigned set. The main contribution of the paper is to prove that under certain assumptions, i) all agents reach consensus on time-averaged estimates, and ii) the estimates approach the pre-assigned set. Conditions for this to happen are related to the connectivity over time of the communication topology and to the approachability principle. Motivations arise in the context of repeated coalitional games with transferable utilities (TU). Here, the algorithm represents a distributed allocation process converging to the core of the game in the limit.

Peter Caines, McGill U. (with Zhongjing Ma, Roland Malhame)

Nash equilibria in radial communication networks via mean field game theory

Mean Field Game theory is developed and applied in this paper to call admission control in a point process model of communication networks. In general the MFG methodology establishes the existence of approximate Nash equilibria for large populations of agents which employ only local feedback and precomputed solutions to the Mean Field equations. In this paper dynamic communication network are modelled by highly symmetric radial loss networks driven by Poisson call request point processes subject to decentralized admission control. A key concept introduced in the analysis in this paper is that of the so-called network decentralized state (NDS) which is a state induced asymptotically (in population size) in a given network under any (randomized) local admission control law when it is common to all agents. Under appropriate assumptions, an analysis of networks in an NDS establishes the existence of Nash equilibria which are achieved for all sufficiently large populations. Computational illustrations of the methodology are included.

Global optimization

Mon.2.H 2053

Global optimization: Algorithms and applications

Organizer/Chair Oleg Prokopyev, University of Pittsburgh · Invited Session

Steffen Rebennack, Colorado School of Mines (with Josef Kalrath)

Good linear approximations for MINLP Problems with tolerance guarantee

For functions depending on one or two variables, we systematically construct optimal breakpoint systems subject to the condition that the linear approximation never deviates more than a given ϵ -tolerance from the original function over a given domain. The optimization problem of computing the minimal number of breakpoints satisfying the ϵ -tolerance leads to semi-infinite problems. We introduce several discretization schemes and algorithms, computing linear approximator, underestimator and overestimator systems with ϵ -tolerance.

Oleg Prokopyev, University of Pittsburgh (with Osman Ozaltin, Andrew Schaefer)

Optimal design of the annual influenza vaccine with autonomous manufacturer

Seasonal influenza (flu) is a major public health concern, and the first line of defense is the flu shot. Frequent updates to the flu shot strains are required, as the circulating strains mutate rapidly. The World Health Organization recommends which flu strains to include in the annual vaccine based on international surveillance. These recommendations have to be made under uncertainty well in advance before the epidemic because the production has many time-sensitive steps. Furthermore, there is a decision hierarchy between the government agencies, who design the flu shot, and the manufacturers, who make it available.

This hierarchy results from the fact that the Committee optimizes the societal vaccination benefit by taking into account production decisions of the manufacturers, who maximize their own profits. The manufacturers' profit maximization problem is affected by the strain selection decisions of the Committee. We quantify the trade-offs involved through a bilevel stochastic mixed-integer program. Calibrated over publicly available data, our model determines the optimal flu shot composition and production in a stochastic and dynamic environment.

Olesya Zhupanska, University of Iowa (with Pavlo Krokhmal, Yana Morenko)

A nonlinear semidefinite programming approach to design of materials

We consider a problem of design of composite materials that consist of multiple phases of "matrix" with randomly oriented "inclusions". It is assumed that spatial orientation of inclusions is prescribed by an orientation distribution function. Our approach allows for constructing lower and upper bounds on the tensor of elastic moduli of the resulting composite material by formulating the corresponding nonlinear semidefinite programming problems. A solution algorithm and computational studies are presented.

Implementations & software

Mon.2.H 1058

Optimization tools for R

Organizer/Chair Erling Andersen, MOSEK ApS · Invited Session

Henrik Friberg, MOSEK

The R-to-MOSEK optimization interface

The Rmosek package enables the solution of large-scale optimization problems from within the R environment. Linear, quadratic and second-order cone optimization with/without integer variables are fully supported via an intuitive, and yet effective, interface to the optimizers of MOSEK. This talk will introduce the package and show its modeling and optimization abilities.

Stefan Theußl, WU Wien (with Kurt Hornik, David Meyer)

ROI – R Optimization Infrastructure package

Currently, R and a wide variety of contributed packages on CRAN as well as other package repositories offer tools to solve many different optimization problems (see the overview at <http://cran.R-project.org/view=Optimization>). However, the user interfaces to available optimizers and the output, i.e., the format of the returned solution, often differ considerably. It is not only the users interested in R as an optimization tool, but also the developers who need to handle different optimization problem classes transparently and who are facing this lack of standardization. Therefore, an integrative multi-purpose optimization framework for R seems to be desirable.

In this talk we present the R Optimization Infrastructure package ROI, an extensible framework for modeling and solving linear as well as nonlinear (possibly mixed-integer) optimization problems. Without the need to learn a domain specific language ROI enables users to employ both, open source and commercial solvers directly within R via so-called plugin packages.

Steven Dirkse, GAMS Development Corporation (with Michael Ferris, Renger van Nieuwkoop)

GDXRWR: Exchanging data between GAMS and R

We discuss GDXRWR (GD-X-R Read/Write), a tool for moving data between GAMS and R. This data exchange is beneficial for those in both user communities. For example, it gives R users the capability to use the superior modeling and optimization capabilities of GAMS, and it allows for visualization and analysis of GAMS data (both pre- and post-solution) directly within R to take advantage of R's wide range of functionality. The freely available tool is based on GD-X (GAMS Data eXchange), a well-established and public API for sharing data.

Integer & mixed-integer programming

Mon.2.H 2013

MILP formulations I

Chair Silvio de Araujo, UNESP/Brazil

Laura McLay, Virginia Commonwealth University

A mixed-integer programming model for enforcing priority list policies in Markov decision processes

Optimal dispatching policies for server-to-customer systems can be identified using Markov decision process models and algorithms, which indicate the optimal server to dispatch to each customer type in each state. Optimal policies are fully state dependent and may be tedious to use in practice. Restricted policies that are partially state dependent and conform to a priority list policy for each type of customer may be easier to use in practice. This research demonstrates how the

optimal priority list policy can be identified by formulating constrained Markov decision processes as mixed integer programming models.

Silvio de Araujo, UNESP/Brazil (with Diego Fiorotto)

Lagrange heuristic for a reformulated capacitated lot sizing problem in parallel machines

The capacitated lot sizing problem with multiple items, setup time and unrelated parallel machines is considered. The aim of this work is to design a Lagrange heuristic that provides good solutions for this problem and strong lower bounds to assess their quality. Based on a strong reformulations of the problem, Lagrange relaxation is applied on the demand constraints and the subgradient optimization procedure is used. A primal heuristic, based on production transfers, is developed to generate feasible solutions (upper bounds). Computational experiments are presented on data sets available from the literature.

Integer & mixed-integer programming

Mon.2.H 2032

Integer programming algorithms II

Chair Serigne Gueye, Université d'Avignon, Laboratoire d'Informatique d'Avignon (LIA)

Hilary Williams, London School of Economics (with John Hooker)

The general solution of a mixed integer programme

We give general formulae for the optimal objective value and solution values of a Mixed Integer Programme (MIP) as a function of the coefficients (objective, matrix and RHS). In order to do this we project out all the variables giving an (attainable) bound on the optimal objective value. This results in the optimal objective value expressed as a finite disjunction of inequalities and linear congruences. While the method is not computationally viable for practical sized MIPs it reveals a lot about their mathematical structure. It also provides a finite method of proving optimality. Hopefully the resultant 'dual' solution also provides useful economic interpretations.

Serigne Gueye, Université d'Avignon, Laboratoire d'Informatique d'Avignon (LIA) (with Philippe Michelon)

Using distance variables for the quadratic assignment problem

The Quadratic Assignment Problem (QAP) is the problem of allocating facilities to locations such as to minimize the sum of a linear and quadratic cost depending on the distances d_{kl} , between facilities k and l , and flows. The Minimum Linear Arrangement (MinLA) is a special case of (QAP) where $d_{kl} = |k - l|$. It has been proposed for MinLA a linear model using distance variables. The lower bound is poor, equal to 0, but can be improved with facets (see [1, 2]). We have independently observed that the distance variables can be used for (QAP), and that some facets are also applicable each time d defines a metric, as the grid graphs in QAPLIB instances. Adding valid inequalities linking D and x , we have tested this model. The result shows a competitive average relative gap of 10.7% with a minimum of 3.4%.

- [1] Liu, W., A. Vannelli. 1995. Generating lower bounds for the linear arrangement problem. *Discrete Applied Mathematics* 59, p. 137–151.
- [2] A. Caprara, A.N. Letchford, and J.J. Salazar-Gonzalez. 2011. Decorous lower bounds for minimum linear arrangement. *INFORM Journal of Computing*, 23(1), p. 26–40.

Integer & mixed-integer programming

Mon.2.MA 004

New methodologies for mixed-integer programming

Organizer/Chair Daniel Bienstock, Columbia University · Invited Session

Juan Pablo Vielma, Massachusetts Institute of Technology (with Daniel Dadush, Santanu Dey, Mustafa Kilinc, Sina Modaresi)

Split cuts for convex nonlinear mixed integer programming

In this talk we study split cuts for convex nonlinear mixed integer programming. We give closed form expressions of split cuts for some quadratic sets and show that the split closure of a strictly convex set is generated by a finite number of split disjunctions, but is not necessarily a polyhedron.

Daniel Bienstock, Columbia University (with Alexander Michalka)

Strong formulations for convex functions over nonconvex sets

In this paper we derive strong linear inequalities for systems representing a convex quadratic over the complement of a convex set, and we present, in several cases, characterizations of the convex hull by polynomially separable linear inequalities. An example of this situation is that of positive definite quadratic over the complement of a polyhedron.

Diego Moran, Georgia Tech (with Santanu Subhas Dey, Juan Pablo Vielma)

Strong dual for conic mixed-integer programs

Mixed-integer conic programming is a generalization of mixed-integer linear programming. We present an extension of the duality the-

ory for mixed-integer linear programming to the case of mixed-integer conic programming. Under a simple condition on the primal problem, we are able to prove strong duality.

Integer & mixed-integer programming

Mon.2.MA 042

Computational integer programming

Organizer/Chair Ricardo Fukasawa, University of Waterloo · Invited Session

Daniel Steffy, Oakland University (with Ambros Gleixner, Kati Wolter)

Improving the accuracy of linear programming solvers with iterative refinement

We describe an iterative refinement procedure for computing extended precision or exact solutions to linear programming problems (LPs). Arbitrarily precise solutions can be computed by solving a sequence of closely related LPs with limited precision arithmetic. The LPs solved at iterations of this algorithm share the same constraint matrix as the original problem instance and are transformed only by modification of the objective function, right-hand side, and variable bounds. Exact computation is used to compute and store the exact representation of the transformed problems, while numeric computation is used for computing approximate LP solutions and applying iterations of the simplex algorithm. We demonstrate that this algorithm is effective in practice for computing extended precision solutions and directly benefits methods for solving LPs exactly over the rational numbers. A proof-of-concept implementation is done within the SoPlex LP solver.

Franz Wesselmann, University of Paderborn (with Uwe Suhl)

Computational experiments with general-purpose cutting planes

General-purpose cutting planes are known to play a crucial role in solving mixed-integer linear programs. We report on computational experiments with families of split cuts which can be generated efficiently such as Gomory mixed-integer cuts, reduce-and-split cuts, lift-and-project cuts and pivot-and-reduce cuts. We also consider several variants of these basic algorithms, e.g., lift-and-project cuts generated from split disjunctions obtained with the reduce-and-split algorithms or reduce-and-split cuts generated using tableau rows produced by the lift-and-project method. Moreover, we present computational results obtained with different variants of multi-row cut separators.

Daniel Espinoza, Universidad de Chile (with Angulo Alejandro)

Cutting and separation for semi-continuous variables

Semi-continuous variables appear naturally when modeling general functions with mixed integer linear programs (MILP), and are widely used in many applications. In this talk we present several classes of inequalities for semi-continuous variables linked together by a knapsack inequality. We present necessary and sufficient conditions for these classes of inequalities to be facet-defining; and also, we describe an approximate lifting scheme, and conditions under which the approximated lifting is exact. Although the separation problem is NP-complete, we present some separation heuristics, as well as extensive testing on instances coming from unit commitment problems. Our results show that, in our test instances, we close in average between 50 and 90 percent of the root LP gap.

Life sciences & healthcare

Mon.2.H 2033

Evolution and phylogenetics

Organizer/Chair Leo van Iersel, Centrum Wiskunde & Informatica · Invited Session

Mareike Fischer, Ernst-Moritz-Arndt-Universität Greifswald

When sets of species make an evolutionary tree unique

In a recent study, Sanderson and Steel defined and characterized so-called phylogenetically decisive sets of species sets. A set is called phylogenetically decisive if regardless of the evolutionary trees chosen for each of its species sets, as long as these trees are compatible with one another, their supertree is always unique. It remained unknown whether the decision if a set of species sets is phylogenetically decisive can always be made in polynomial time. This question was one of the "Penny Ante" questions of the Annual New Zealand Phylogenetics Meeting 2012. In my talk, I will explain phylogenetic decisiveness and demonstrate a new mathematical characterization, which then leads to a polynomial time algorithm – both for the (simpler) case of rooted trees as well as for the (more complicated) unrooted case.

Steven Kelk, Maastricht University (with Nela Lekic, Simone Linz, Celine Scornavacca, Leen Stougie, Leo van Iersel)

Cycle killer ... qu'est-ce que c'est? On the comparative

approximability of hybridization number and directed feedback vertex set

We show that the problem of computing the hybridization number of two rooted binary phylogenetic trees on the same set of taxa X has a constant factor polynomial-time approximation if and only if the problem of computing a minimum-size feedback vertex set in a directed graph (DFVS) has a constant factor polynomial-time approximation. The latter problem, which asks for a minimum number of vertices to be removed from a directed graph to transform it into a directed acyclic graph, is one of the problems in Karp's seminal 1972 list of 21 NP-complete problems. Despite considerable attention from the combinatorial optimization community, it remains to this day unknown whether a constant factor polynomial-time approximation exists for DFVS. Our result thus places the (in)approximability of hybridization number in a much broader complexity context. On the positive side, we use results from the DFVS literature to give an $O(\log r \log \log r)$ approximation for the hybridization number where r is the correct value.

Celine Scornavacca, ISEM, Université Montpellier II (with Steven Kelk)

Constructing minimal phylogenetic networks from softwired clusters is fixed parameter tractable

Here we show that, given a set of clusters C on a set of taxa X , where $|X| = n$, it is possible to determine in time $f(k) \cdot \text{poly}(n)$ whether there exists a level- $\leq k$ network (i.e. a network where each biconnected component has reticulation number at most k) that represents all the clusters in C in the softwired sense, and if so to construct such a network. This extends a polynomial time result from Kelk et al (On the elusiveness of clusters, IEEE/ACM Transactions on Computational Biology and Bioinformatics, 2012). By generalizing the concept of "level- k generator" to general networks, we then extend this fixed parameter tractability result to the problem where k refers not to the level but to the reticulation number of the whole network.

Logistics, traffic, and transportation

Mon.2.H 0106

Branch-and-price algorithms in transportation

Organizers/Chairs Florian Dahms, RWTH Aachen University; Marco Lübbecke, RWTH Aachen University · Invited Session

Robert Voll, TU Dortmund University (with Uwe Clausen)

Branch-and-price-and-cut for railroad blocking plans

We present a consolidation problem from wagonload traffic, which is a production form in railway freight traffic. A huge number of OD-requests -each of them consists of only a small number of wagons- has to be routed through the railway network. Wagons from different OD-pairs (relations) are consolidated in reclassification yards in order to use trains jointly for parts of their routes. The route of each relation is determined by so called Blocking Plans which shall be optimized. The objective is to minimize the sum of train and reclassification costs. We consider a multicommodity flow problem with elements of a fixed charge problem. A column generation pattern developed earlier is extended to a Branch-and-Price-algorithm. Our branching rule destroys the simple subproblem structure of the aforementioned column generation approach, but we overcome this problem by dynamical programming. We can take advantage from our branching rule by deriving effective cuts. Numerical results are presented and compared to solutions provided by commercial solvers. We also analyze the impact of our cuts empirically. First experiments are very promising.

Michel Seixas, University of Sao Paulo (with André Mendes)

Branch-and-price for a rich vehicle routing and scheduling problem

This study considers a vehicle routing problem with time windows, accessibility restrictions on customers and a fleet that is heterogeneous with regard to capacity and average speed. A vehicle can perform multiple routes per day, all starting and ending at a single depot, and it is assigned to a single driver, whose total work hours are limited. A column generation algorithm embedded in a branch-and-bound framework is proposed. The column generation pricing subproblem required a specific elementary shortest path problem with resource constraints algorithm to deal with the possibility for each vehicle to perform multiple routes per day and to deal with the need to determine the workday beginning instant of time within the planning horizon. To make the algorithm efficient, a constructive heuristic and a metaheuristic based on tabu search were also developed.

Florian Dahms, RWTH Aachen University (with Markus Bohlin, Holger Flier, Sara Gestreluis, Matús Mihalák)

An extended formulation for allocating classification tracks in hump yards

A major task in railway operations is shunting trains in a hump yard. Freight cars need to be assigned to classification tracks where they can be formed into outgoing trains. Often the objective is to minimize the

number of shunting operations like pulling out and rolling in cars to the hump yard.

Our model is based on the processes at the Hallsberg hump yard in Sweden. The problem formulation derived from these processes was already shown to be NP-hard by Bohlin et al.

Natural compact MIP formulations so far have only yielded very weak linear relaxations and could not be used to efficiently generate optimal solutions for problem instances of reasonable size.

We present an extended formulation that produces a very tight linear relaxation and can be efficiently solved via column generation for large problem instances. For several real world instances we are now able to produce optimal solutions.

Furthermore we discuss issues like symmetry, branching decisions and problem specific heuristics necessary to improve the solving process.

Logistics, traffic, and transportation

Mon.2.H 0111

Advances in machine learning

Organizer/Chair Vivek Farias, MIT · Invited Session

Paul Grigas, Massachusetts Institute of Technology (with Robert Freund)

Proximal subgradient and dual averaging for sequential decision-making and non-smooth optimization

We analyze and show interconnections between prox subgradient and dual averaging methods for both sequential decision making as well as non-smooth convex optimization. Our sequential decision-making problem context generalizes the allocation problem addressed in the Hedge Algorithm as studied by Baes and Burgisser. Furthermore, our framework provides a new interpretation and extensions of the algorithm AdaBoost, where the distribution on examples provides the primal variables and the final classifier arises naturally as a weighted average of dual variables. Lastly, we examine connections between various first-order method, and propose new first-order methods as well.

Vivek Farias, MIT (with Nikhil Bhat, Ciamac Moallemi)

Non-parametric approximate dynamic programming via the kernel method

We present a "kernelized" variant of a recent family of approximate dynamic programming algorithms we have dubbed "smoothed approximate linear programs". Our new algorithm is non-parametric in that it does not require a basis function architecture and develops a value function approximation with accuracy that improves with the size of the training data set. We describe the efficient implementation of this method, and present sample complexity bounds and approximation guarantees that effectively extend state of the art guarantees for ADP to the non-parametric setting. In summary, we believe this is the first practical *non-parametric* ADP algorithm with performance guarantees.

Sahand Negahban, MIT (with Alekh Agarwal, Martin Wainwright)

Noisy matrix decomposition via convex relaxation: Optimal rates in high dimensions

We analyze a class of estimators based on convex relaxation for solving high-dimensional matrix decomposition problems. The observations are noisy realizations of a linear transformation \mathbb{X} of the sum of an (approximately) low rank matrix Θ^* with a second matrix Γ^* endowed with a complementary form of low-dimensional structure; this set-up includes many statistical models of interest, including factor analysis, multi-task regression, and robust covariance estimation. We derive a general theorem that bounds the Frobenius norm error for an estimate of the pair (Θ^*, Γ^*) obtained by solving a convex optimization problem that combines the nuclear norm with a general decomposable regularizer. We specialize our general result to two cases that have been studied in past work: low rank plus an entrywise sparse matrix, and low rank plus a columnwise sparse matrix. For both models, our theory yields non-asymptotic Frobenius error bounds for both deterministic and stochastic noise matrices. Moreover, for the case of stochastic noise matrices and the identity observation operator, we establish matching lower bounds on the minimax error.

Mixed-integer nonlinear programming

Mon.2.MA 005

Global mixed-integer nonlinear optimization II

Organizer/Chair Ignacio Grossmann, Carnegie Mellon University · Invited Session

Brage Knudsen, Norwegian University of Science and Technology (with Andrew Conn, Bjarne Foss)

Mixed integer optimization of the late-life performance of shale-gas wells

Efficient shale-gas recovery requires a large number of wells in order to maintain a sustainable total gas supply. The wells and the pro-

duction pads are often widely spread over a large geographical area, and interconnected by comprehensive surface gathering lines. We present a discrete time mixed integer nonlinear program (MINLP) for optimal scheduling of shale-gas multi-well pads. The MINLP model is formulated by using a dynamic reservoir proxy model and a nonlinear well model for each well, and we show how shut-ins may be efficiently scheduled to prevent liquid loading and boost late-life rates for these types of wells. Furthermore, by using a simplified well model and performing a linear reformulation, we do a preliminary comparison of solving the scheduling problem as an MILP compared to the MINLP.

Gonzalo Guillén-Gosálbez, Universitat Rovira I Virgili (with Pedro Copado, Ignacio Grossmann)

Solving mixed-integer linear-fractional programming problems via an exact MILP reformulation

We present a method to solve mixed-integer linear-fractional programming (MILFP) problems in which the objective function is expressed as a ratio of two linear functions and the equality and inequality constraints are all linear. Our approach extends the transformation of Charnes and Cooper (1962), originally devised for linear-fractional programs with continuous variables, to handle the mixed-integer case. In essence, we reformulate the MILFP into an equivalent mixed-integer linear program (MILP) that makes use of auxiliary continuous variables. The solution of this MILP, which can be obtained by standard branch-and-cut methods, provides the global optimum of the original MILFP. Numerical results show that our strategy outperforms the most widely used general-purpose mixed-integer nonlinear programming solution methods (i.e., outer approximation – available in DICOPT –, nonlinear branch and bound – SBB –, and extended cutting plane, alphaBB) as well as the branch-and-reduce global optimization algorithm implemented in BARON.

Charnes, A., Cooper, W. W. (1962). *Naval Research Logistics Quarterly*, 9: 181–196.

Pedro Castro, Laboratório Nacional de Energia e Geologia (LNEG) (with Ignacio Grossmann, João Teles)

Multiparametric disaggregation as a new paradigm for global optimization of mixed-integer polynomial programs

Multiparametric Disaggregation involves discretization of the domain of one of the variables appearing in a bilinear term, the basic building block to tackle higher order polynomials. Alternative numeric representation systems can be employed (e.g., decimal, binary) with the user specifying the accuracy level for the approximation. With this, the original MINLP can be approximated by an upper bounding MILP, which might be easier to solve to global optimality. In this work, we propose a lower bounding relaxation MILP, where a truncation error is defined for the parameterized variables. Since the higher the chosen accuracy, the tighter the formulation, we can easily construct a global optimization algorithm starting with 1 significant digit (first iteration) and ending when the optimality gap is lower than a given tolerance. Starting with Disjunctive Programming models, we show that the new relaxation, although looser, leads to a better performance than the one from piecewise McCormick relaxations (using univariate and uniform domain partitioning). The primary cause is the linear vs. exponential increase in problem size for an order of magnitude reduction in optimality gap.

Multi-objective optimization

Mon.2.H 1029

Efficient set representations

Organizer/Chair Luís Paquete, University of Coimbra · Invited Session

Michael Stiglmayr, University of Wuppertal

The multicriteria linear bottleneck assignment problem

We present a solution method for the multicriteria linear bottleneck assignment problem (MLBAP), which is the multicriteria analogon of the well studied linear bottleneck assignment problem. Our algorithm is an extension of the single criteria threshold algorithm. We define a residual graph by specifying a (multicriteria) threshold vector, such that all of its edges have cost dominated by the threshold. Any complete matching in this residual graph is a candidate for an efficient solution with at least the threshold values. The computation of matchings in the residual graph is realized by an efficient update of augmenting paths. Based on our method, which computes the complete efficient set, we also suggest an approximation scheme for the efficient set with an adjustable quality. The uniformity and the dispersity of this representation can be bounded during the run of the algorithm. While we restrict ourselves to bicriteria cases, we show possible extensions to multiple criteria.

Luís Paquete, University of Coimbra (with Carlos Fonseca, Kathrin Klamroth, Michael Stiglmayr)

Concise representation of nondominated sets in discrete multicriteria optimization

The problem of finding a representative subset of the nondominated point set of a discrete multicriteria optimization problem with respect to uniformity and coverage is introduced. Provided that the decision maker

is able to indicate the number of points to visualize, a subset of well-spread points (uniformity) that are close enough to the remaining points (coverage) is of interest.

Finding a representative p -point subset with respect to uniformity and coverage can be formulated as a combination of p -dispersion and p -center facility location problems, respectively, with a special location structure. In this work, polynomial-time dynamic programming algorithms to find representative subsets with respect to each of these measures in the two-dimensional case are presented. Moreover, the multicriteria version of this problem is shown to be solvable also in polynomial time using dynamic programming. The extension of these and related problems to larger dimensions will be discussed.

Florian Seipp, University of Kaiserslautern (with Stefan Ruzika)

A polynomial time approach for the multiple objective minimum spanning tree problem

The minimum spanning tree problem is a well-studied problem in combinatorial optimization. Whereas the single objective version can be solved in polynomial time by greedy algorithms, the multiple objective version is known to be intractable and NP-hard. Even worse, the number of both supported and unsupported nondominated points may be exponentially large in the number of edges of the underlying graph. In this talk, it is shown that it is however possible to bound the number of extremal supported nondominated points polynomially. The result is based on the theory of arrangements of hyperplanes. It immediately implies that the first phase of the two-phases method, i.e., computing the nondominated frontier, can be accomplished by solving a polynomial number of weighted sum problems. A solution approach is presented which demonstrates how this can be achieved algorithmically.

Nonlinear programming

Mon.2.H 0107

Methods for nonlinear optimization II

Chair Csizmadia Zsolt, FICO

Art Gorka, Erskine College (with Michael Kostreva)

Parallel direction finding algorithm in method of feasible directions

A Parallel version of the Method of Feasible Directions algorithm is presented. Parallelization allows for finding multiple directions simultaneously on parallel machines. The algorithm is tested on a number of problems with known solutions from Hock-Schittkowski and compared with sequential algorithms. A numberfold speedup ratios are reported.

James Hungerford, University of Florida (with William Hager)

Edge directions in polyhedral optimization

We consider the problem of maximizing a continuously differentiable function $f(x)$ over a polyhedron $\mathcal{P} \subset \mathbb{R}^n$. We present new first and second order optimality conditions for this problem which are stated in terms of the derivatives of f along directions parallel to the edges of \mathcal{P} . We show that for a special class of quadratic programs, local optimality can be checked in polynomial time. Finally, we present a new continuous formulation for a well known discrete optimization problem: the vertex separator problem on a graph G . Easily checked optimality conditions for this problem are derived via the theory of edge directions. These optimality conditions are shown to be related to the existence of edges at specific locations in the graph.

Csizmadia Zsolt, FICO

Pros and cons of first order methods for solving general nonlinear problems

Second order methods to solve non-linear problems are often the best off the shelf methods to solve general non-linear problems due to their robustness and favorable un-tuned convergence properties. However, there are several problem classes, where either due to the special structure of the problem, or their size make first order approaches several magnitudes faster compared to their second order counterparts. First order methods exhibit several well know numerically unfavorable properties; successful applications often rely on efficient, problem specific methods of addressing these challenges. The talk will focus on practical examples and applications where sequential linear programming approaches are either superior, or can be adjusted to achieve significantly better performance than second order methods if the right problem formulation or algorithmic features are used.

Nonlinear programming

Mon.2.H 0110

Nonlinear optimization II

Organizers/Chairs Frank E. Curtis, Lehigh University; Daniel Robinson, Johns Hopkins University · Invited Session

Daniel Robinson, Johns Hopkins University (with Frank Curtis, Zheng Han)

A primal-dual active-set method for convex QP

We present a rapidly adapting active-set method for solving large-scale strictly convex quadratic optimization problems. In contrast to traditional active-set methods, ours allows for rapid changes in the active set estimate. This leads to rapid identification of the optimal active set, regardless of the initial estimate. Our method is general enough that it can be utilized as a framework for any method for solving convex quadratic optimization problems. Global convergence guarantees are provided for two variants of the framework. Numerical results are also provided, illustrating that our framework is competitive with state-of-the-art solvers on most problems, and is superior on ill-conditioned problems. We attribute these latter benefits to the relationship between the framework and a semi-smooth Newton method.

Sven Leyffer, Argonne National Laboratory

Large-scale nonlinear optimization solvers

We describe the development of a suit of tools and solvers for large-scale nonlinearly constrained optimization problems. We emphasize methods that can operate in a matrix-free mode and avoid matrix factorizations. Our framework implements a range of two-phase active-set methods, that are required, for example, for fast resolves in mixed-integer solvers. In the first phase, we estimate the active set, and in the second phase we perform a Newton step on the active constraints. We show that our framework can be designed in a matrix-free mode, and analyze its convergence properties. We show that allowing a small number of active-set changes in the Newton step improves convergence.

Elizabeth Wong, University of California, San Diego (with Philip Gill, Daniel Robinson)

Regularized quadratic programming methods for large-scale QP

We present a regularized method for large-scale quadratic programming (QP). The method requires the solution of a sequence of bound-constrained subproblems defined in terms of both the primal and dual variables. The subproblems may be solved using a conventional active-set method, which would involve the solution of a regularized KKT system at each step, or a method based on gradient projection. In the convex case, the solution of the bound-constrained subproblem is also a solution of the QP subproblem for a stabilized sequential quadratic programming (SQP) method. Numerical results are presented.

Nonlinear programming

Mon.2.H 0112

Structures, complexities, and eigenvalues of tensor forms and polynomial functions

Organizer/Chair Shuzhong Zhang, University of Minnesota · Invited Session

Shuzhong Zhang, University of Minnesota (with Bo Jiang, Zhening Li)

Cones of nonnegative quartic polynomial functions and their applications

Polynomial and tensor optimization models have proved to be useful in a wide range of applications in engineering and scientific computation. Applications aside, the structure of higher order polynomial/tensor functions however remains largely unknown. For example, the computational status to test if a quartic function is convex or not had remained an open problem until 2010 when Ahmadi et al. proved that it is in fact strongly NP hard. In this talk we discuss six particular convex cones generated from the nonnegative quartic polynomial functions. Our goal is to illustrate the rich structure of nonnegative quartic polynomial functions. In particular, these convex cones are in decreasing order, much like the Russian Matryoshka dolls, with varying computational complexities. We discuss the modeling power and applications of these convex cones. In the context of these cones we also introduce an interesting result known as Hilbert's identity, and discuss its role in our study.

Lek-Heng Lim, University of Chicago (with Christopher Hillar)

3-tensors as the boundary of tractability

Why do problems in numerical computing become intractable as they transition from linear to nonlinear or convex to nonconvex? We shall argue that 3-tensor problems form the boundary separating the tractability of linear algebra and convex optimization from the intractability of polynomial algebra and nonconvex optimization – 3-tensor analogues of many efficiently computable matrix problems are NP-hard. Our list includes: determining the feasibility of a system of bilinear equations, deciding whether a 3-tensor possesses a given eigenvalue,

singular value, or spectral norm; approximating an eigenvalue, eigenvector, singular vector, or spectral norm; determining the rank or a best rank-1 approximation to a 3-tensor. Additionally, some of these problems have no polynomial time approximation schemes, some are undecidable over \mathbb{Q} , and at least one enumerative version is #P-complete. Restricting these problems to symmetric 3-tensors does not alleviate their NP-hardness.

Qingzhi Yang, Nankai University, China

Some properties of tensors' eigenvalues and related optimization problem

In this talk, I will focus on the properties of tensors' eigenvalues and related optimization problem. The tensor is an array of high dimensional data, which can be viewed as the extension of the vector and matrix. In the past some years, especially recent years, due to the needs of real problems, the study on the tensors attracts a great attention. Several different definitions of eigenvalues of tensors were presented, and various properties with respect to tensors' eigenvalues were put forward, some interesting conclusions were generalized from the matrix to tensor, such as the Perron-Frobenius theorem for nonnegative matrix. In addition, for some problems one has to find the largest or smallest eigenvalues of tensors, which can be written as some special constrained optimization problem(s). I will introduce the recent development in properties of tensors' eigenvalues as well as the algorithms for solving the related optimization problem(s).

Nonsmooth optimization

Mon.2.H 1012

Constrained variational inequalities: Approximation and numerical resolution

Organizer/Chair Juan Peyrouquet, Universidad Tecnica Federico Santa Maria · Invited Session

Juan Peyrouquet, Universidad Tecnica Federico Santa Maria (with Pierre Frankel)

Lagrangian-penalization algorithm for constrained optimization and variational inequalities

Let X, Y be real Hilbert spaces. Consider a bounded linear operator $A : X \rightarrow Y$ and a nonempty closed convex set $C \subset Y$. In this paper we propose an inexact proximal-type algorithm to solve constrained optimization problems

$$\inf\{f(x) : Ax \in C\},$$

where f is a proper lower-semicontinuous convex function on X ; and variational inequalities

$$0 \in Mx + A^*N_C(Ax),$$

where $M : X \rightrightarrows X$ is a maximal monotone operator and N_C denotes the normal cone to the set C . Our method combines a penalization procedure involving a bounded sequence of parameters, with the predictor corrector proximal multiplier method. Under suitable assumptions the sequences generated by our algorithm are proved to converge weakly to solutions of the aforementioned problems. As applications, we describe how the algorithm can be used to find sparse solutions of linear inequality systems and solve partial differential equations by domain decomposition.

Yoon Garcia Ramos, Universidad Del Pacifico (with Marc Lassonde)

Representable monotone operators and limits of sequences of maximal monotone operators

We show that the lower limit of a sequence of maximal monotone operators on a reflexive Banach space is a representable monotone operator. As a consequence, we obtain that the variational sum of maximal monotone operators and the variational composition of a maximal monotone operator with a linear continuous operator are both representable monotone operators.

Felipe Alvarez, Universidad de Chile (with Julio Lopez)

A strictly feasible Bundle method for solving convex nondifferentiable minimization problems under second-order constraints

We will describe a bundle proximal method with variable metric for solving nonsmooth convex optimization problems under positivity and second-order cone constraints. The proposed algorithm relies on a local variable metric which is induced by the Hessian of the log barrier. An appropriate choice of a regularization parameter ensures the well-definedness of the algorithm and forces the iterates to belong to the relative interior of the feasible set. Also, under suitable but fairly general assumptions, we will show that the limit points of the sequence generated by the algorithm are optimal solutions. Finally, we will report some computational results on several test nonsmooth problems.

Optimization in energy systems

Mon.2.MA 549

Optimization in energy systems

Organizer/Chair Jon Lee, University of Michigan · Invited Session

Timo Lohmann, Colorado School of Mines (with Steffen Rebennack)

Stochastic hydro-thermal scheduling with CVaR risk constraints in deregulated markets

In the regulated electricity market, a power producer's goal is to satisfy his customers' electricity demand while minimizing his expected cost of operating his power system. In the deregulated market, a power producer has no longer to meet the electricity demand of his customers, but is able to trade the electricity in the market. This complicates the problem as uncertainty of spot prices and risk appetite have to be considered in addition. The objective of optimization is the maximization of expected net profit of the power system in the mid-term horizon. In our case the power system is hydro-dominated and the resulting multi-stage stochastic programming problem contains jointly uncertainties in the hydro inflows and electricity spot prices. These kinds of models are usually solved with the SDDP algorithm. For this special case we need to use a hybrid SDP/SDDP algorithm and we enhance it with CVaR risk constraints.

Nicola Secomandi, Carnegie Mellon University (with Margot Francois, Nadarajah Selvaprabu)

Approximate linear programming relaxations for commodity storage real option management

Real option management of commodity storage typically gives rise to an intractable Markov Decision Process (MDP). We derive novel approximate dynamic programs for this MDP from partitioned surrogate relaxations of an approximate linear program. We estimate lower bounds and dual upper bounds on the value of storage for a seasonal commodity (natural gas) and a non-seasonal commodity (oil). Our lower bounds essentially match the best known lower bounds for the natural gas storage instances, and are near-optimal for the oil instances, which are new. Our upper bounds either match or improve those available in the literature for natural gas, but are weaker than an exchange-option based upper bound from the literature for the oil instances. We use a tractable version of the problem to highlight the source of the bias in our estimated upper bounds.

Yongpei Guan, University of Florida (with Ruiwei Jiang, Jean-Paul Watson, Ming Zhao)

A branch-and-cut algorithm for the Multi-stage Stochastic Unit Commitment Problem

Due to the uncertainty from both supply and demand sides, power grid operation is generally a stochastic nonlinear problem for regulated electricity market. In this talk, we propose a Multi-stage Stochastic Unit Commitment (MSUC) model to address this problem, where we approximate the nonlinear fuel cost functions by piecewise linear functions. Furthermore, we employ a branch-and-cut algorithm to solve MSUC by constructing strong inequalities for the substructures of the constraints.

Optimization in energy systems

Mon.2.MA 550

Network operation under failures and losses

Chair Maicon Evaldt, University of Vale do Rio do Sinos (UNISINOS)

Richard Chen, Sandia National Laboratories (with Amy Cohn, Neng Fan, Ali Pinar, Jean-Paul Watson)

Survivability-constrained generation unit commitment with post-contingency corrective recourse

We consider the problem of optimizing generation unit commitment under load uncertainty while ensuring $N-k-\epsilon$ survivability criterion. This survivability criterion is a generalization of the well-known $N-k$ criterion, and it requires that at least $(1 - \epsilon^k)$ fraction of the total demand is met even after failures of any k system components, for all $k = 0, 1, \dots, k^{\max}$. We present a mixed-integer formulation of this problem that takes into account both transmission and generation component failures. We propose a cutting plane algorithm that can avoid combinatorial explosion in the number of contingencies that needs to be considered, by seeking vulnerabilities in intermediary solutions and constraining the search space accordingly. Our empirical studies on modified instances from the IEEE test systems showed the effectiveness of our proposed techniques.

Jose Canto dos Santos, Unisinos - Brazil (with Iverson Costa)

New genetic algorithms for contingencies selection in electric power systems

The importance of a reliable supply of electricity to the industrial society is unquestionable. In a control center of an electrical utility, an important computational task is the security analysis. In this task, contingency is the output of operation of an equipment and contingencies

selection is the determination of the most severe contingencies for the system. Even with the current technological advances, an analysis in real time of all possible failures in a large grid is impractical. In this work we present a method to perform efficiently the selection of multiple contingencies. The problem is modeled as a combinatorial optimization problem, and solved by genetic algorithms that make efficient the screenings of the associated non-convex and non-linear search spaces. We developed a robust method, which considers aspects of power flow and voltage that was tested with an IEEE test system and with a large real network, considering double outages of branches. Excellent results with levels of accuracy close to 100%, when compared with an exact method, obtained with scans of reduced portions of search spaces are presented.

Maicon Evaldt, University of Vale do Rio do Sinos (UNISINOS) (with Luis Basilio, Rodrigo de Figueiredo, José Vicente dos Santos, Márcio Refael Stracke)

Optimal allocation of equipment for monitoring and identification of commercial losses in distribution networks

In 2011, the Brazilian National Agency of Electrical Energy estimated that economic losses due to fraud in distribution networks are around US. 4.6 billion a year in Brazil. This paper focuses on this problem and presents a system for monitoring and identification of commercial losses. The proposed solution is based on low cost power meters installed at strategic points of the network, communicating by wireless with a control central. Inconsistencies in billing are identified based on the network model and data received from power meters. A linear programming method is employed to define the areas of installation that produce the best coverage results, considering distance, number of consumers and power demand. Graphic and mathematic tools PSL DMS, GEPATH and Google Earth are employed to represent the grid under test. The methodology is applied in a real network of 4 km of extension. Economic viability and payback analysis for the proposed solution are also presented. The main contribution of this work, for electrical utilities, is a reliable indication of commercial losses in each monitored segment of the distribution network.

PDE-constrained opt. & multi-level/multi-grid meth.

Mon.2.MA 415

Iterative solution of PDE constrained optimization and subproblems

Chair Lutz Lehmann, Humboldt-Universität zu Berlin

Pavel Zhtobich, University of Edinburgh (with Jacek Gondzio)

Multilevel quasiseparable matrices in PDE-constrained optimization

Discretization of PDE-constrained optimization problems leads to linear systems of saddle-point type. Numerical solution of such systems is often a challenging task due to their large size and poor spectral properties. In this work we propose and develop the novel approach to solving saddle-point systems, which is based on the exploitation of low-rank structure of discretized differential operators and their inverses. This structure is known in the scientific literature as "quasiseparable". One may think of a usual quasiseparable matrix as of a discrete analog of Green's function of a one-dimensional differential operator. The remarkable feature of such matrices is that almost all of the algorithms with them have linear complexity. We extend the range of applicability of quasiseparable matrices to problems in higher dimensions. In particular, we construct a class of preconditioners that can be computed and applied at a linear computational cost. Their use with appropriate Krylov subspace methods leads to algorithms for solving saddle-point systems mentioned above of asymptotically linear complexity.

Gregor Kriwet, University of Marburg

Covariance matrix computation for parameter estimation in nonlinear models solved by iterative linear algebra methods

For solving parameter estimation (PE) and optimum experimental design (OED) problems we need covariance matrix of the parameter estimates. So far numerical methods for PE and OED in dynamic processes have been based on direct linear algebra methods which involve explicit matrix factorizations. They are originally developed for systems of non-linear DAE where direct linear algebra methods are more effective for forward model problems than iterative methods. On the other hand for large scale constrained problems with sparse matrices of special structure, e.g., originating from discretization of PDE, direct linear algebra methods are not competitive with iterative linear algebra methods even for forward models. Hence, for PDE models, generalizations of iterative linear algebra methods to the computation of covariance matrices are crucial for practical applications. One of the intriguing results is that solving nonlinear constrained least squares problems by Krylov type methods we get as a by-product the covariance matrix and con-

fidence intervals. The talk is based on joint work with H. G. Bock, E. Kostina, O. Kostyukova, I. Schierle and M. Saunders.

Lutz Lehmann, Humboldt-Universität zu Berlin (with Torsten Bosse, Andreas Griewank)

Optimal sequencing of primal, adjoint and design steps.

Many researchers have used design optimization methods based on a user specified primal state iteration, corresponding adjoint iterations and appropriately preconditioned design steps. Our goal is to develop heuristics for the sequencing of these three subtasks in order to optimize the convergence rate of the resulting coupled iteration. We present numerical results that confirm the theoretical predictions.

Robust optimization

Mon.2.H 3503

Robust nonlinear optimization

Chair Daniel Fleischman, Cornell University

Martin Mevissen, IBM Research Ireland (with Emanuele Ragnoli, Jia Yu)

Distributionally robust optimization for polynomial optimization problems

In many real-world optimization problems, one faces the dual challenge of hard nonlinear functions in both objective and constraints and uncertainty in some of the problem parameters. Often, samples for each uncertain parameter are given, whereas its actual distribution is unknown. We propose a novel approach for constructing distributionally robust counterparts of a broad class of polynomial optimization problems. The approach aims to use the given samples, not only to approximate the support of the unknown distribution or the first and second order moments, but also its density. We show that polynomial optimization problems with distributional uncertainty sets defined via density estimates are particular instances of the generalized problem of moments with polynomial data and employ Lasserre's hierarchy of SDP relaxations to approximate the distributionally robust solutions. As a result of using distributional uncertainty sets, we obtain a less conservative solution than classical robust optimization. We demonstrate the potential of our approach for a range of polynomial optimization problems including linear regression and water network problems.

Hans Pirnay, Process Systems Engineering, RWTH Aachen (with Wolfgang Marquardt)

An algorithm for robust optimization of nonlinear dynamic systems

Nonlinear model predictive control (NMPC) is an attractive control methodology for chemical processes. In NMPC, the control is computed by solving a dynamic optimization problem constrained by a differential algebraic model of the underlying process. These systems are often subject to unknown disturbances, which, if not taken into account, can lead to deterioration of the control quality, and even instability of the control loop.

To overcome this problem, the dynamic optimization problem has to be formulated in a robust way such that feasibility is guaranteed under all circumstances. This leads to a bi-level formulation with a dynamic lower level problem. Unfortunately, even simple dynamical models used for NMPC lead to non-convex feasible sets, which tremendously complicates the solution. In this talk, we present an algorithm for bi-level dynamic optimization in the context of NMPC. To deal with the non-convexity, recent advances in dynamic global optimization are employed. In addition, we take advantage of the parametric nature of the lower level problem to speed up the computation and make the algorithm viable for real-time applications.

Daniel Fleischman, Cornell University (with Mike Todd)

On the trade-off between robustness and value

Linear programming problems may be formed based on data collected with measurement error, which may make the optimal solution to the problem with the nominal parameters infeasible for the "real parameters". One way to approach this difficulty is by using robust optimization, where we form an uncertainty set \mathcal{E} around the nominal parameter vector, and a solution has to be feasible for any vector in \mathcal{E} . One question that arises is how large the uncertainty set \mathcal{E} should be. The larger it is, the safer we are, but at the same time, our solution becomes worse. We study such questions when the uncertainty set for each constraint is a uniform scale factor times a fixed ellipsoid, and propose a simple, easy to compute approximate solution depending on the scale factor.

Sparse optimization & compressed sensing

Mon.2.H 1028

Sparse optimization and generalized sparsity models

Organizer/Chair Gitta Kutyniok, Technische Universität Berlin · Invited Session

Rayan Saab, Duke University (with Michael Friedlander, Hassan Mansour, Ozgur Yilmaz)

Recovering compressively sampled signals using partial support information

In this talk, we address the recovery conditions of weighted ℓ_1 minimization for signal reconstruction from compressed sensing measurements when partial support information is available. We show that if at least half of the (partial) support information is accurate, then weighted ℓ_1 minimization is stable and robust under weaker conditions than the analogous sufficient conditions for standard ℓ_1 minimization. Moreover, weighted ℓ_1 minimization provides better bounds on the reconstruction error in terms of the measurement noise and the compressibility of the signal to be recovered. We illustrate our results with numerical experiments.

Emmanuel Candes, Stanford University (with Yonina Eldar, Thomas Strohmer, Vladislav Voroninski)

PhaseLift: Exact phase retrieval via convex programming

This talk introduces a novel framework for phase retrieval, a problem which arises in X-ray crystallography, diffraction imaging, astronomical imaging and many other applications. Our approach combines multiple structured illuminations together with ideas from convex programming to recover the phase from intensity measurements, typically from the modulus of the diffracted wave. We demonstrate empirically that any complex-valued object can be recovered from the knowledge of the magnitude of just a few diffracted patterns by solving a simple convex optimization problem inspired by the recent literature on matrix completion. More importantly, we also demonstrate that our noise-aware algorithms are stable in the sense that the reconstruction degrades gracefully as the signal-to-noise ratio decreases. Finally, we present some novel theory showing that our entire approach may be provably surprisingly effective.

Gitta Kutyniok, Technische Universität Berlin

Clustered sparsity

The novel research area of compressed sensing surprisingly predicts that high-dimensional signals, which allow a sparse representation by a suitable basis or, more generally, a frame, can be recovered from what was previously considered highly incomplete linear measurements, by using efficient algorithms. Lately, more attention has been paid to the fact that in most applications the nonzero entries of the sparse vector do not arise in arbitrary patterns, but are rather highly structured. It also became evident that often the interactions between columns of the sensing matrix in ill-posed problems are not arbitrary, but rather geometrically driven.

In this talk, we will introduce what we coin clustered sparsity to provide a meaningful mathematical framework for these considerations. We will discuss sparse recovery results and applications to data separation and inpainting. It is also intriguing to realize that this framework often naturally requires solving a different ℓ_1 minimization problem, namely the minimization on the analysis rather than the synthesis side. This is related to the recently introduced co-sparsity model.

Stochastic optimization

Mon.2.MA 141

Applications in natural resources

Chair Ralf Lenz, Zuse Institute Berlin (ZIB)

Gankhuyag Danzan, Mongolian University of Science and Technology (with Buyantogtokh Danzan, Khajidsuren Navaandamba)

Regional economical mathematical models considering ecological factors

Mongolia is experiencing rapid economic development attributable to growth in the mining sector. Exploration by major national and international mining companies has identified substantial reserves of coal, copper and other minerals. Exploitation of these reserves is under way with production expected to grow significantly in the next five years. However, while the nation is experiencing significant GDP growth, the exploitation of mineral reserves is having a negative impact on the environment. Natural resources are being depleted, chemicals are entering atmosphere, water is being polluted with toxic metals, pasture land is being destroyed and the incidence of sickness among the local population is ever increasing.

There is now a growing demand for the development of mathematical models and related software to analyze the impact of and the inter-relationship of different factors on the regional economies affected by the mining industry. Statistical and dynamical models have been de-

veloped, defined and solved using multi-extremals and stochastic programming problems.

Ralf Lenz, Zuse Institute Berlin (ZIB) (with Frédéric Blank, Guido Dr. Sand, Martin Dr. Weiser)

Optimization of water network operation under uncertainties

Water utilities operate their water networks in a very conservative manner. To be able to satisfy a volatile demand, the current operation procedure focuses on maintaining high water levels in the reservoirs. This results in higher operation costs due to inefficiencies regarding pressure levels and pump energy consumption. While common approaches available in literature and as software packages use deterministic water demand predictions as a base, the focus of this talk considers uncertainties in the water demands prediction. We present a methodology, which targets on lowering the minimum water storage level bounds without increasing the risk of running out of water. This is done by modeling uncertainties in water demand and applying stochastic programming techniques. Controlling the water storage levels allows the decrease of the artificial high bounds. Reducing water storage levels implies a reduction of pumping costs, as pumps do not have to work against these high heads. Finally we present the results by means of a small practical problem.

Adriana Piazza, Universidad Técnica Federico Santa María (with Bernardo Pagnoncelli)

The optimal harvesting problem under price uncertainty

We study the exploitation of a one species forest plantation when timber price is governed by a stochastic process. The work focuses on providing closed expressions for the optimal harvesting policy in terms of the parameters of the price process and the discount factor. We assume that harvest is restricted to mature trees older than a certain age and neglect natural mortality and growth after maturity. We use stochastic dynamic programming techniques to characterize the optimal policy for two important cases: (i) when prices follow a geometric Brownian motion we completely characterize the optimal policy, (ii) if prices are governed by a mean reverting (Ornstein-Uhlenbeck) process we provide sufficient conditions, based on explicit expressions for reservation prices, assuring that harvesting everything available is optimal. For the Ornstein-Uhlenbeck process, we propose a policy based on a reservation price that performs well in numerical simulations. In both cases we solve the problem for every initial condition and the best policy is obtained without imposing any ad hoc restrictions such as maximum sustained yield or convergence to a predefined final state.

Stochastic optimization

Mon.2.MA 144

Production, inventory and project management

Chair Takashi Hasuike, Osaka University

Wen-Lung Huang, National Chung Cheng University (with Shih-Pin Chen)

Optimal aggregate production planning with fuzzy data

This paper investigates the optimization problem of aggregate production planning (APP) with fuzzy data. From a comprehensive viewpoint of conserving the fuzziness of input information, this paper proposes a method that can completely describe the membership function of the performance measure. The idea is based on the well-known Zadeh's extension principle which plays an important role in fuzzy theory. In the proposed solution procedure, a pair of mathematical programs parameterized by possibility level is formulated to calculate the bounds of the optimal performance measure. Then the membership function of the optimal performance measure is constructed by enumerating different values. An example is solved successfully for illustrating the validity of the proposed approach. Solutions obtained from the proposed method contain more information, and can offer more chance to achieve the feasible disaggregate plan. This is helpful to the decision-maker in practical applications.

Ali Randa, Middle East Technical University (with Mustafa Dođru, Cem İyigün, Ulas Ozen)

Static-dynamic uncertainty strategy for a single-item stochastic inventory control problem

We consider a single-stage inventory system facing non-stationary stochastic demand of the customers in a finite planning horizon. Motivated by practice, the replenishment times need to be determined and frozen once and for all at the beginning of the horizon while decision on the exact replenishment quantities can be deferred until the replenishment time. This operating scheme is referred as a static-dynamic uncertainty strategy in the literature. We consider dynamic fixed/variable cost of ordering, linear holding costs as well as dynamic penalty costs, and upper/lower limits on order quantities. We prove that the optimal ordering policy is a base stock policy. We develop heuristics for computing the optimal policy parameters for longer planning horizons because the optimal ordering periods and the associated base stock levels need exponentially exhaustive search based on dynamic programming.

We then evaluate the efficiency of our heuristics by numerical examples. We also investigate the NP hardness of the problem considering the computational time required with the size of the problem.

Takashi Hasuike, Osaka University

Risk control approach to critical path method in mathematical programming under uncertainty

This paper considers a risk control approach to find a critical path in the project scheduling network under several uncertainties for each activity duration time and the improvement imputing some materials and human resources. As a mathematical model of proposed approach, the mathematical programming problem based on Critical Path Method is introduced. Furthermore, in order to formulate risk of control factors and each random relation between two successive processes mathematically, quantile-based robust parameters and a time expanded network for the given static project scheduling network are introduced. The proposed model is initially a multi-objective and stochastic programming problem, and hence, it is hard to solve this problem directly without setting some optimal criterion. In this paper, an integrated function for the multi-objective and randomness is introduced. By performing deterministic equivalent transformations, the strict solution algorithm is developed.

Stochastic optimization

Mon.2.MA 376

Stochastic mixed-integer programming

Organizer/Chair Maarten van der Vlerk, University of Groningen · Invited Session

Lanah Evers, TNO (with Ana Barros, Kristiaan Glorie, Herman Monsuur, Suzanne Ster)

The orienteering problem under uncertainty: Robust optimization and stochastic programming compared

The Orienteering Problem (OP) is a generalization of the well-known traveling salesman problem and has many interesting applications in logistics, tourism and defense. To reflect real-life situations, we focus on an uncertain variant of the OP. Two main approaches that deal with optimization under uncertainty are stochastic programming and robust optimization. We will explore the potentialities and bottlenecks of these two approaches applied to the uncertain OP. We will compare the known robust approach for the uncertain OP (the robust orienteering problem) to the new stochastic programming counterpart (the two-stage orienteering problem). The application of both approaches will be explored in terms of their suitability in practice.

Ward Romeijnnders, University of Groningen (with Willem Klein Haneveld, Maarten van der Vlerk)

On the performance of a class of convex approximations for integer recourse models

We consider the performance of the convex approximations introduced by Van der Vlerk (2004) for the class of integer recourse problems with totally unimodular (TU) recourse matrices. We show that the main theorem in Van der Vlerk (2004) needs stronger assumptions. As a result, a performance guarantee for the convex approximations is lacking in general. In order to obtain such a performance guarantee, we first analyze the approximations for simple integer recourse models. Using a new approach we improve the existing error bound for these models by a factor 2. We use insights from this analysis to obtain an error bound for complete integer recourse problems with TU recourse matrices. This error bound ensures that the performance of the approximations is good as long as the dispersion of the random variables in the model is large enough.

Simge Kucukyavuz, Ohio State University (with Dinakar Gade, Suvrajeet Sen)

Decomposition algorithms with Gomory cuts for two-stage stochastic integer programs

We consider a class of two-stage stochastic integer programs (SIP) with binary variables in the first stage and general integer variables in the second stage. We develop decomposition algorithms akin to the L -shaped or Benders' decomposition scheme by utilizing Gomory cuts method to obtain iteratively tighter approximations of the second stage integer programs. We show that the proposed methodology is flexible in that it allows several modes of implementation, all of which lead to finitely convergent algorithms. This development allows both disjunctive as well as Gomory cuts to be included within finitely convergent decomposition algorithms for SIP. Such disparate collections of cuts have proved to be indispensable for the success of branch-and-cut algorithms in deterministic IP, and we are hopeful that the introduction of Gomory cuts within a decomposition algorithm will be just as valuable for SIP. We will illustrate the use of these cuts both within a pure cutting plane, as well as a branch-and-cut based decomposition algorithm.

Telecommunications & networks

Mon.2.H 3002

Wireless networks

Chair André Berger, Maastricht University

Sergey Astrakov, Design Technological Institute of Digital Techniques

The full efficient monitoring of stripe with external deployment sensors

We are considering a problem for min-density covering of a stripe in wireless sensor networks. There is the special condition for networks such as sensor unit not located in area of stripe. Since energy consumption of sensing is proportional to the coverage space, a problem of power efficient sensing of a plane region could be reduced to the problem of search min-density covering of a region within disks with adjustable sensing ranges. We studied several new efficient regular models of covering and have offered a general classification.

Ashutosh Nigam, IIM Lucknow (with Yogesh Agarwal)

A Lagrangian heuristic for delay constrained relay node placement problem in wireless sensor networks

The Optimal Delay Constrained Relay Node Placement problem is stated as: given the locations of the root node, a set of source nodes and a set of candidate relay nodes and delays provided on each possible links (edges), find a minimal set of relay nodes amongst the candidate relay nodes such that there is a path, within the specified delay bound, between each source node and the root node via the selected relay nodes only. In our work, we propose an algorithm which uses the constrained shortest path using Dijkstra and Lagrangian heuristic. The proposed polynomial time algorithm (complexity $O(n * \log(d_{max}/m))$, where n is the number of candidate relay nodes, m is the number of edges and d_{max} is the pre-specified delay bound) provides close to optimal solution (in most of the cases the optimality gap is within 10%). We also compare our algorithm with other existing polynomial time algorithms and demonstrate the efficiency of our algorithm in terms of solution strength as well as the CPU Time.

André Berger, Maastricht University (with James Gross, Tobias Harks, Simon Tenbusch)

Constrained resource assignments: Fast algorithms and applications in wireless networks

Resource assignment problems occur in a vast variety of applications, from scheduling problems over image recognition to communication networks, just to name a few. While in some of the applications an assignment of the resources may be needed only once, often the assignment has to be computed more often for different scenarios. In that case it is essential that the assignments can be computed very fast. Moreover, implementing different assignments in different scenarios may come with a certain cost for the reconfiguration of the system.

In this paper we consider the problem of determining optimal assignments sequentially over a given time horizon, where consecutive assignments are coupled by constraints which control the cost of reconfiguration. We develop fast approximation and online algorithms for this problem with provable approximation guarantees and competitive ratios.

Finally, we establish the applicability of our model and our algorithms in the context of OFDMA wireless networks, finding a significant performance improvement for the total bandwidth of the system using our algorithms.

Variational analysis

Mon.2.H 2035

Eigenvalue and semi-infinite optimization

Chair Sara Grundel, MPI Magdeburg

Sara Grundel, MPI Magdeburg (with Michael Overton)

Variational analysis of the spectral abscissa for defective and derogatory matrices

The spectral abscissa and radius are respectively the largest of the real parts and the largest of the moduli of the eigenvalues of a matrix. They are non-Lipschitz, nonconvex functions on the space of complex $n \times n$ matrices. To motivate our work, we briefly discuss a spectral radius optimization problem for parametrized matrices arising from subdivision surfaces, a method to construct smooth surfaces from polygonal meshes used in computer graphics and geometric modeling. In this case, we find that the minimizing matrix is both defective and derogatory: the Jordan form of the optimal matrix has four blocks corresponding to the eigenvalue zero, with sizes 4, 3, 2 and 2. Generally, spectral functions are not Clarke regular at such points in matrix space, and hence their subdifferential analysis is complicated. By refining results of Burke and Overton, we address the simplest such case, presenting a complete characterization of the Mordukhovich subgradients of the

spectral abscissa for a matrix with an eigenvalue having two Jordan blocks of size 2 and 1.

Tatiana Tchemisova, University of Aveiro

On a constructive approach to optimality conditions for convex SIP problems with polyhedral index sets

In the paper, we consider a problem of convex Semi-Infinite Programming with multi-dimensional index set in the form of a multi-dimensional polyhedron. In study of these problems we apply the approach suggested in our recent paper [Kost-Tchem] and based on the notions of immobile indices and their immobility orders. For this problem, we formulate explicit optimality conditions that do not use constraint qualifications and have the form of criterion. The comparison with other known optimality conditions is provided.

Julia Eaton, University of Washington Tacoma (with James Burke)

On the subdifferential regularity of functions of roots of polynomials

Eigenvalue optimization problems arise in the control of continuous and discrete time dynamical systems. The spectral abscissa and spectral radius are examples of functions of eigenvalues, or spectral functions, connected to these problems. A related class of functions are polynomial root functions. In 2001, Burke and Overton showed that the abscissa mapping on polynomials is subdifferentially regular on the monic polynomials of degree n . We extend this result to the class of max polynomial root functions which includes both the polynomial abscissa and the polynomial radius mappings. The approach to the computation of the subgradient simplifies that given by Burke and Overton and provides new insight into the variational properties of these functions.

Variational analysis

Mon.2.H 2051

Variational analysis and economic equilibrium

Organizer/Chair Alejandro Jofré, Universidad de Chile · Invited Session

Abderrahim Jourani, Université de Bourgogne (with Alejandro Jofré)

A characterization of the free disposal condition for nonconvex economies on infinite-dimensional commodity spaces

Our aim in this talk is to prove a geometric characterization of the free disposal condition for non convex economies on infinite-dimensional commodity spaces even if the cone and the production set involved in the condition have empty interior such as in l^1_+ with the positive cone l^1_+ . We then use this characterization to prove existence of Pareto and weak Pareto optimum points. We also explore a notion of approximate-Pareto optimum point, called extremal system. We show that the free disposal hypothesis alone assures extremality of the production set with respect to some set.

Jean-Marc Bonnisseau, Université Paris 1 Panthéon-Sorbonne (with Achis Chery)

On the rank of payoff matrices with long-term assets

We consider a stochastic financial exchange economy with a finite date-event tree representing time and uncertainty and a nominal financial structure with possibly long-term assets. We exhibit a sufficient condition under which the return matrix and the full return matrix have the same rank. This generalizes previous results of Angeloni-Cornet and Magill-Quinzii involving only short-term assets. We then derive existence results with assumptions only based on the fundamentals of the economy.

Alejandro Jofré, Universidad de Chile (with Terry Rockafellar, Roger Wets)

The robust stability of every equilibrium in economic models of exchange even under relaxed standard conditions

In an economic model of exchange of goods, the structure can be specified by utility functions. Under utility conditions identified here, every equilibrium will simultaneously be stable with respect to shifts in the associated holdings of the agents and with respect to the Walrasian tatonnement process of price adjustment. This fact, seemingly contrary to widespread belief, is revealed by paying close attention not only to prices but also to the proximal status of initial holdings. The conditions on the concave utility functions are standard for stability investigations, in that they invoke properties coming from second derivatives, but significantly relaxed in not forcing all goods to be held only in positive amounts. Recent advances in variational analysis provide the support needed for working in that context. The stability results also point the way toward further developments in which an equilibrium might evolve in response to exogenous inputs to the agents' holdings, or extractions.

Approximation & online algorithms

Mon.3.H 3010

Location and routing problems

Chair Artem Panin, Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences

Tim Nonner, IBM Research - Zurich

Polynomial-time approximation schemes for shortest path with alternatives

Consider the generic situation that we have to select k alternatives from a given ground set, where each element in the ground set has a random arrival time and cost. Once we have done our selection, we will greedily select the first arriving alternative, and the total cost is the time we had to wait for this alternative plus its random cost. Our motivation to study this problem comes from public transportation, where each element in the ground set might correspond to a bus or train, and the usual user behavior is to greedily select the first option from a given set of alternatives at each stop. First, we give an $O(n(\log n + d^3))$ time algorithm for exponentially distributed arrival times, where n is the number of stops in the transportation network and d is the maximal number of buses or trains leaving any stop, making this approach practicable for large networks if d is relatively small, and second, for uniformly distributed arrival times, we give a PTAS under reasonable assumptions. These results are obtained by combining methods from low-rank quasi-concave optimization with fractional programming. We finally complement them by showing that general distributions are NP-hard.

Adrian Bock, TU Berlin (with Elyot Grant, Jochen Könnemann, Laura Sanità)

The school bus problem

The School Bus Problem is an NP-hard vehicle routing problem in which the goal is to route buses that transport children to a school such that for each child, the distance travelled on the bus relative to the shortest distance from the child's home to the school does not exceed a given regret threshold. Subject to this constraint and bus capacity limit, the goal is to minimize the number of buses required. We also consider the variant where we have a fixed number of buses to use and the goal is to minimize the maximum regret. We present logarithmic factor approximation algorithms as well as constant factor approximations for the special case where all children and the school are located on a fixed tree.

Artem Panin, Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences

On approximability some location and pricing problems

We consider location and pricing problems based on different pricing strategies: mill, uniform and discriminatory pricing. We suggest the bilevel mixed integer formulations. We prove that these problems are NP-hard in the strong sense. We present the polynomial time poly-approximate algorithms for these problems.

Combinatorial optimization

Mon.3.H 3004

Interactions between optimization and game theory in scheduling

Organizer/Chair Neil Olver, MIT · Invited Session

Marc Uetz, University of Twente (with Jelle Duives, Ruben Hoeksma)

Mechanism design for single machine scheduling by ILP

We consider the classical single machine scheduling problem to minimize total weighted completion times $\sum w_j C_j$. The problem is easily solved in polynomial time, but here we assume that data is private information to the jobs. This gives rise to a situation where jobs may strategize by misreporting their private data. In order to do optimization in such a setting, also incentive constraints have to be taken into account. Since Myerson's seminal work on optimal auction design, it is well known how such mechanism design problems can be solved when private data is single-dimensional, but not much is known for multi-dimensional mechanism design problems, neither in general nor for the scheduling problem at hand. In the spirit of what is called automated mechanism design, we use integer linear programming models to find optimal scheduling mechanisms for the 2-dimensional mechanism design problem. So far, this approach is prohibitive for all but toy problems, yet it allows to generate and test hypotheses. This way, we gain new insights into optimal mechanisms for the scheduling problem at hand.

Ruben Hoeksma, University of Twente (with Marc Uetz)

Price of anarchy for minsum related machine scheduling

We consider related machine scheduling to minimize the total completion time $\sum C_j$. This problem is well known to be solved in polynomial time by a classical algorithm of Horowitz and Sahni. Instead of the

centralized optimal solution, however, we are interested in the situation where each job individually chooses the machine on which it is processed. We analyze the quality of the resulting Nash equilibria in relation to the objective value in the optimal solution, also known as the price of anarchy. Complementing recent results by Cole et al. on the unrelated machine problem where the price of anarchy equals exactly 4, we show that the local SPT rule results in a price of anarchy between $e/(e-1)$ and 2. To obtain the upper bound of 2, we use a smoothness argument in the flavor of recent work of Roughgarden, blended with a new characterization of the structure of optimal solutions.

Neil Olver, MIT (with Richard Cole, Jose Correa, Vasilis Gkatzelis, Vahab Mirrokni)

Approximation algorithms for scheduling via coordination mechanisms

We investigate the problem of scheduling on multiple unrelated machines, where the goal is to minimize the weighted sum of completion times. We primarily consider the game-theoretic version of the problem, where each job is an agent aiming to minimize its own completion time. However, as one outcome of our work we obtain the first *combinatorial* constant factor approximation algorithm for the NP-hard optimization problem.

We consider a number of different *policies*; rules specifying the scheduling on a machine for a given assignment. The most obvious choice is Smith's rule; for a given assignment of jobs to machines, this yields the optimal schedule. However, we show that other policies that give a suboptimal scheduling actually have much better equilibrium schedules, due to better incentives. By finding an approximate Nash equilibrium for one such policy via local search, we obtain a factor $2 + \epsilon$ approximation algorithm.

These results are obtained by the application of a common technique: a mapping of the strategy vectors into a carefully chosen inner product space. Once this structure is in place, the proofs are relatively short and elegant.

Combinatorial optimization

Mon.3.H 3005

Exact and approximation algorithms on graphs

Organizer/Chair Frédéric Meunier, CERMICS, École des Ponts · Invited Session

Denis Cornaz, Université Paris-Dauphine (with Meurdesoif Philippe)

Strengthening Lovász bound for coloring with a new graph transformation

Let $\alpha(G)$ and $\bar{\chi}(G)$ denote the stability number and the clique-partition number of G , respectively. Using a new graph transformation, one constructs a new operator Φ which associates to any graph parameter β such that $\alpha(G) \leq \beta(G) \leq \bar{\chi}(G)$ for all graphs G , a graph parameter Φ_β such that $\alpha(G) \leq \Phi_\beta(G) \leq \bar{\chi}(G)$ for all graphs G . We prove that $\vartheta(G) \leq \Phi_\vartheta(G)$ and that $\Phi_{\bar{\chi}_f}(G) \leq \bar{\chi}_f(G)$ for all graphs G , where ϑ is Lovász theta function and $\bar{\chi}_f$ is the fractional clique-partition number. $\Phi_\vartheta - \vartheta$ is unbounded and numerical experiments show that Φ_ϑ is a significant better lower bound for $\bar{\chi}$ than ϑ .

Frédéric Meunier, CERMICS, École des Ponts (with Daniel Chemla, Roberto Wolfler Calvo)

A routing problem raised by self-service bike hiring systems

Operating bike-sharing systems raises many problems. One of the most natural is the repositioning of the bikes with the help of one or many trucks.

We focus in this talk on the case when there is only one truck. We are given a graph whose vertices model stations. The current repartition of the bikes is known. We wish to move these bikes with the truck in order to reach a target repartition, and we want to realize this task at a minimal cost. The concrete motivation corresponds to the situation encountered at the end of the night, when very few bikes are moving.

A part of the talk will be devoted to special polynomial cases and to approximation algorithms. An efficient method able to solve in practice instances of reasonable size will also be presented: this method combines the exact computation of a natural lower bound and a local search exploiting theoretical properties of the problem. Open questions will also be discussed.

Henning Bruhn, Université Pierre et Marie Curie (with Akira Saito)

Clique or hole in claw-free graphs

Given a claw-free graph and two non-adjacent vertices x and y without common neighbours we prove that there exists a hole through x and y unless the graph contains the obvious obstruction, namely a clique separating x from y . As applications we derive an algorithm to verify whether there is a hole through two given vertices as well as an algorithm for the 3-in-a-tree problem in claw-free graphs.

Combinatorial optimization

Mon.3.H 3008

Distances in graphs

Organizers/Chairs Christian Wulff-Nilsen, University of Southern Denmark; Glencora Borradaile, Oregon State University · Invited Session

Rachit Agarwal, University of Illinois at Urbana-Champaign

The space-stretch-time tradeoff in distance oracles

We present distance oracles for weighted undirected graphs that return distances of stretch 2 and less. For the realistic case of sparse graphs, our distance oracle exhibit the three-way trade-off between space, stretch and query time – a phenomenon that does not occur in dense graphs. In particular, for any positive integer t and for any $1 \leq \alpha \leq n$, our distance oracle is of size $O(m + n^2/\alpha)$ and returns stretch $(1 + 2/(t+1))$ distances in time $O((\alpha\Delta)^t)$, where $\Delta = 2m/n$ is the average degree of the graph. The query time can be further reduced to $O((\alpha + \Delta)^t)$ at the expense of a small additive stretch.

Consider, for example, the realistic case of graphs with $m = \tilde{O}(n)$ edges and fix the query time to be $\tilde{O}(n^{2/3})$. Our distance oracles, then, return stretch 2 distances using space $O(n^{4/3})$ and stretch 5/3 distances using space $O(n^{5/3})$.

Christian Wulff-Nilsen, University of Southern Denmark

Approximate distance oracles with improved preprocessing and query time

Given an undirected graph G with m edges, n vertices, and non-negative edge weights, and given an integer $k \geq 2$, we show that a $(2k-1)$ -approximate distance oracle for G of size $O(kn^{1+1/k})$ and with $O(\log k)$ query time can be constructed in $O(\min\{kmn^{1/k}, \sqrt{km} + kn^{1+c/\sqrt{k}}\})$ time for some constant c . This simultaneously improves the $O(kmn^{1/k})$ preprocessing and the $O(k)$ query time of Thorup and Zwick. For any $0 < \epsilon \leq 1$, we also give an oracle of size $O(kn^{1+1/k})$ that answers $((2+\epsilon)k)$ -approximate distance queries in $O(1/\epsilon)$ time. At the cost of a k -factor in size, this improves the $128k$ approximation achieved by the constant query time oracle of Mendel and Naor and approaches the best possible tradeoff between size and stretch, implied by a widely believed girth conjecture of Erdős. We can match the $O(n^{1+1/k})$ size bound of Mendel and Naor for any constant $\epsilon > 0$ and $k = O(\log n / \log \log n)$.

Liam Roditty, Bar-Ilan University (with Mihai Patrascu, Mikkel Thorup)

A survey on distance oracles

Computing distances is one of the most fundamental computational problems. In many applications we are not really interested in *all* distances, we want the ability to retrieve them quickly. Thorup and Zwick (2005) initiated the theoretical study of data structures capable of representing approximated distances efficiently, in terms of space requirement and query time. Given an n -vertex weighted undirected graph with m edges, they show that for any integer $k \geq 1$ it is possible to preprocess the graph in $\Theta(mn^{1/k})$ time and generate a compact data structure of size $O(n^{1+1/k})$. For each pair of vertices, it is then possible to retrieve a stretch k approximate distance in $O(k)$ time. Recently, Pătraşcu and Roditty (2010) broke the long-standing theoretical status-quo in the field of distance oracles. They obtained, in particular, a distance oracle for unweighted graphs of size $O(n^{5/3})$ that can supply in $O(1)$ time an estimated distance in the range $[d, 2d+1]$, where d is the actual distance between the two vertices queried.

Combinatorial optimization

Mon.3.H 3012

Scheduling II

Chair Alexander Tesch, TU-Berlin / Zuse Institute Berlin (ZIB)

Matthew Oster, Rutgers University (with Jonathan Eckstein)

A branch and cut algorithm for solving capacitated max k -cut with an application in scheduling

We model the scheduling of a symmetric multi-track conference as a capacitated version of the combinatorial optimization problem known as Maximum k -Cut (MKC). We solve this NP-hard problem to optimality within a branch-and-bound framework equipped with a semidefinite programming relaxation of MKC, enhanced with triangle and clique cuts, as well as new problem-specific cuts (e.g., what we call star-capacity cuts, total-capacity cuts, etc.). We also introduce a new heuristic for generating feasible solutions at most tree nodes. Test results for

small to moderate-sized conferences will be discussed for both serial and parallel implementations of our algorithm.

Alexander Tesch, TU-Berlin / Zuse Institute Berlin (ZIB)

Optimization of the ISMP 2012 schedule

Your favourite sessions overlap at the same time, the lecture halls are overcrowded or your talk just wasn't added to a suitable date-slot? Assignment-problems like that may occur in conference planning like this year's ISMP. To avoid such incidents hopefully we developed a MIP with multi-criteria objective to handle several conflicts like an even offering of different clusters, room-capacity-requirements and prevention of time-dependant-crossovers of popular talks. Therefore we integrated a priority model for the talks to evaluate high visitor rates. We also used an approach to relax the original assignment problem and introduce a heuristic to solve the master problem from the obtained relaxed solution.

Combinatorial optimization

Mon.3.H 3013

Constrained clustering

Organizer/Chair Peter Gritzmann, TU München · Invited Session

Steffen Borgwardt, Technische Universität München

On the diameter of partition polytopes and vertex-disjoint cycle cover

We study the combinatorial diameter of partition polytopes, a special class of transportation polytopes. They are associated to partitions of a set $X = \{x_1, \dots, x_n\}$ of items into clusters C_1, \dots, C_k of prescribed sizes $\kappa_1 \geq \dots \geq \kappa_k$. We derive upper bounds on the diameter in the form of $\kappa_1 + \kappa_2$, $n - \kappa_1$ and $\lfloor \frac{n}{2} \rfloor$. This is a direct generalization of the diameter-2 result for the Birkhoff polytope. The bounds are established by a constructive, graph-theoretical approach which reveals that special sets of vertices in graphs that decompose into cycles can be covered by a set of vertex-disjoint cycles. Finally, we give exact diameters for partition polytopes with $k = 2$ or $k = 3$ and prove that, for all $k \geq 4$ and all κ_1, κ_2 , there are cluster sizes $\kappa_3, \dots, \kappa_k$ such that the diameter of the corresponding partition polytope is at least $\lfloor \frac{4}{3} \kappa_2 \rfloor$.

Anastasia Shakhshshneyder, Technische Universität München (with Andreas Brieden, Peter Gritzmann)

Hardness and non-approximability of constrained clustering

This talk is devoted to constrained clustering, where one would like to divide a given set of objects into groups according to some objective function. The objects are usually represented as points in the Minkowski space, and the objective function is a function of the distances between them. We assume that the points have weights and the total weight of points in a cluster is prescribed to be in a given interval.

The constrained clustering problems are known to be \mathcal{NP} -hard. But there is not much knowledge about their approximation status. In this talk we present new inapproximability results. In particular, we show that if the dimension is a part of the input, the problems are \mathcal{APX} -hard and do not admit a 1.09-approximation. These results hold even if the points have equal weights and an overlapping of the clusters is allowed. Moreover, when fractional assignments of the points are not permitted, there is no polynomial-time $2^{|x|}$ -approximate algorithm, where $|x|$ is the size of an input x . The hardness persists even if the points lie on a line.

Andreas Brieden, Universität der Bundeswehr München (with Peter Gritzmann)

Constrained clustering with convex objective function

In this talk the computation of strongly and weakly balanced clusterings that are optimal with respect to the sum of pairwise cluster distances is considered. As it turns out, the problem can be reduced to a well studied norm-maximization problem over much lower dimensional polytopes called gravity polytopes. The vertices of these polytopes are closely related to power diagrams which implies nice properties of any optimal clustering and also of approximate solutions. Furthermore this reduction allows for much better approximation results.

Combinatorial optimization

Mon.3.H 3021

Equilibria and combinatorial structures

Organizer/Chair Britta Peis, TU Berlin · Invited Session

Walter Kern, Universiteit Twente

Cooperative games and fractional programming

Straightforward analysis of core-related optimization problems leads to interesting fractional versions of standard (combinatorial) opti-

mization problems and challenging open conjectures. We focus on two particular cases: TSP and bin packing.

Tamás Király, Eötvös University, Budapest (with Attila Bernáth, Mádi-Nagy Gergely, Pap Gyula, Pap Júlia)

Multiplayer multicommodity flows

We investigate the Multiplayer Multicommodity Flow Problem, a version of the multicommodity flow problem where players have different subnetworks and commodities over a common node set. Pairs of players have contracts where one of them agrees to route the flow of the other player (up to a given capacity) between two specified nodes. In return, the second player pays an amount proportional to the flow value.

We show that the social optimum can be computed by linear programming. In contrast, an equilibrium solution, although it always exists under some natural conditions, is PPAD-hard to find. We analyze hardness in relation to the structure of the digraph formed by the contracts between players, and prove that an equilibrium can be found in polynomial time if every strongly connected component of this digraph is a cycle.

Tom McCormick, UBC Sauder School of Business (with Britta Peis)

A primal-dual algorithm for weighted abstract cut packing

Hoffman and Schwartz developed the Lattice Polyhedron model and proved that it is totally dual integral (TDI), and so has integral optimal solutions. The model generalizes many important combinatorial optimization problems such as polymatroid intersection, cut covering polyhedra, min cost aborescences, etc., but has lacked a combinatorial algorithm. The problem can be seen as the blocking dual of Hoffman's Weighted Abstract Flow (WAF) model, or as an abstraction of ordinary Shortest Path and its cut packing dual, so we call it Weighted Abstract Cut Packing (WACP). We develop the first combinatorial algorithm for WACP, based on the Primal-Dual Algorithm framework. The framework is similar to that used by Martens and McCormick for WAF, in that both algorithms depend on a relaxation by a scalar parameter, and then need to solve an unweighted "restricted" subproblem. The WACP subroutine uses an oracle to solve a restricted abstract cut packing/shortest path subproblem using greedy cut packing, breadth-first search, and an update that achieves complementarity slackness. This plus a standard scaling technique yields a polynomial combinatorial algorithm.

Complementarity & variational inequalities

Mon.3.MA 041

Analysis and learning in variational inequalities

Organizer/Chair Shu Lu, University of North Carolina at Chapel Hill · Invited Session

Hao Jiang, University of Illinois at Urbana-Champaign (with Sean Meyn, Uday Shanbhag)

Learning parameters and equilibria in noise-corrupted Cournot games with misspecified price functions

We consider an oligopolistic setting in which myopic firms compete in a repeated Nash-Cournot game. In accordance with the Cournot assumption, prices are set based on aggregate output levels. We develop distributed learning schemes in a regime where firms are ignorant of a complete specification of an affine price function; specifically, firms learn the equilibrium strategy and correct the misspecification in the price function by simultaneously incorporating noise-corrupted observations and demand function. Differentiated by informational assumptions, two sets of schemes are developed and their performance is demonstrated on a networked Nash-Cournot game:

(1) Learning under common knowledge with unobservable aggregate output: Here, payoff functions and strategy sets are public knowledge (a common knowledge assumption) but aggregate output is unobservable. When firms may observe noise-corrupted prices, distributed best response schemes are developed which allow for simultaneously learning the equilibrium strategy and the misspecified parameter in an almost-sure sense. Furthermore, these statements may be extended to accommodate nonlinear generalizations of the demand function.

Stephen Robinson, University of Wisconsin-Madison

Local analysis of variational conditions

We will present a mathematical framework for local analysis of variational conditions in finite-dimensional spaces, and will illustrate some of its applications. We will also illustrate some forms of the fundamental regularity conditions for this analysis, and discuss connections among these.

Andreas Fischer, TU Dresden (with Francisco Facchinei, Markus Herrich)

A framework for smooth and nonsmooth equations with nonisolated solutions

The problem of solving a system of possibly nonsmooth equations appears in several applications. For example, complementarity problems or Karush-Kuhn-Tucker conditions of an inequality constrained

optimization problem can be written in this way. A new local iterative framework for solving systems of equations under additional convex constraints will be presented. In particular, the framework includes conditions for local superlinear convergence. These conditions enable the application to nonsmooth systems with nonisolated solutions. Different algorithms belonging to the framework will be described.

Complementarity & variational inequalities

Mon.3.MA 313

Optimization and equilibrium problems II

Organizers/Chairs Christian Kanzow, University of Würzburg; Michael Ulbrich, Technische Universität München · Invited Session

Sebastian Albrecht, Technische Universität München (with Stefan Glasauer, Marion Leibold, Michael Ulbrich)

Inverse optimal control of human locomotion

The general hypothesis of our approach is that human motions are (approximately) optimal for an unknown cost function subject to the dynamics. Considering tasks where participants walk from a start to an end position and avoid collisions with crossing persons, the human dynamics are modeled macroscopically on a point-mass level. The locomotion problem results in an optimal control problem and in case of a crossing interferer an MPC-like approach seems suitable. The task of inverse optimal control is to find the cost function within a given parametrized family such that the solution of the corresponding optimal control problem approximates the recorded human data best. Our solution approach is based on a discretization of the continuous optimal control problem and on a reformulation of the bilevel problem by replacing the discretized optimal control problem by its KKT-conditions. The resulting mathematical program with complementarity conditions is solved by using a relaxation scheme and applying an interior-point solver. Numerical results for different navigation problems including hard and soft constraints in the optimal control problem are discussed.

Francisco Facchinei, University of Rome La Sapienza (with Christian Kanzow, Simone Sagratella)

Solving quasi-variational inequalities via their KKT conditions

We propose to solve a general quasi-variational inequality by using its Karush-Kuhn-Tucker conditions. To this end we use a globally convergent algorithm based on a potential reduction approach. We establish global convergence results for many interesting instances of quasi-variational inequalities, vastly broadening the class of problems that can be solved with theoretical guarantees. Our numerical testings are very promising and show the practical viability of the approach.

Christian Kanzow, University of Würzburg (with Alfio Borzi)

Nash equilibrium multiobjective elliptic control problems

The formulation and the semismooth Newton solution of Nash equilibria multiobjective elliptic optimal control problems are presented. Existence and uniqueness of a Nash equilibrium is proved. The corresponding solution is characterized by an optimality system that is approximated by second-order finite differences and solved with a semismooth Newton scheme. It is demonstrated that the numerical solution is second-order accurate and that the semismooth Newton iteration is globally and locally quadratically convergent. Results of numerical experiments confirm the theoretical estimates and show the effectiveness of the proposed computational framework.

Conic programming

Mon.3.H 2036

Semidefinite programming applications

Chair Tomohiko Mizutani, Kanagawa University

Sunyoung Kim, Ewha W. University (with Masakazu Kojima, Makoto Yamashita)

A successive SDP relaxation method for distance geometry problems

We present a numerical method using cliques and successive application of sparse semidefinite programming relaxation (SFSDP) for determining the structure of the conformation of large molecules from the Protein Data Bank. A subproblem of a clique and its neighboring nodes is initially solved by SFSDP and refined by the gradient method. This subproblem is gradually expanded to the entire problem by fixing the nodes computed with high accuracy as anchors and successively applying SFSDP. Numerical experiments show that the performance of the proposed algorithm is robust and efficient.

Robert Freund, MIT (with Han Men, Ngoc Cuong Nguyen, Jaime Peraire, Joel Saa-Seoane)

Implementation-robust design: Modeling, theory, and application to photonic crystal design with bandgaps

We present a new theory for incorporating considerations of implementation into optimization models quite generally. Computed so-

lutions of many optimization problems cannot be implemented directly due to (i) the deliberate simplification of the model, and/or (ii) human factors and technological reasons. We propose a new alternative paradigm for treating issues of implementation that we call "implementation robustness." This paradigm is applied to the setting of optimizing the fabricable design of photonic crystals with large band-gaps. Such designs enable a wide variety of prescribed interaction with and control of mechanical and electromagnetic waves. We present and use an algorithm based on convex conic optimization to design fabricable two-dimensional photonic crystals with large absolute band gaps. Our modeling methodology yields a series of finite-dimensional eigenvalue optimization problems that are large-scale and non-convex, with low regularity and non-differentiable objective. By restricting to appropriate eigen-subspaces, we reduce the problem to a sequence of small-scale SDPs for which modern SDP solvers are successfully applied.

Tomohiko Mizutani, Kanagawa University (with Makoto Yamashita)

SDP relaxations for the concave cost transportation problem

We present a hierarchy of semidefinite programming (SDP) relaxations for solving the concave cost transportation problem (CCTP) with p suppliers and q demanders. The key idea of the relaxation methods is in the change of variables to CCTPs, and due to this, we can construct SDP relaxations whose matrix variables depend on $\min\{p, q\}$ at each relaxation order. The sequence of optimal values of SDP relaxations converges to the global minimum of the CCTP as the relaxation order goes to infinity. We show the performance of the relaxation methods through numerical experiments.

Conic programming

Mon.3.H 2038

Matrix optimization

Organizer/Chair Defeng Sun, National University of Singapore · Invited Session

Houduo Qi, University of Southampton

Computing the nearest Euclidean distance matrix

The Nearest Euclidean distance matrix problem (NEDM) is a fundamental computational problem in applications such as multidimensional scaling and molecular conformation from nuclear magnetic resonance data in computational chemistry. Especially in the latter application, the problem is often a large scale with the number of atoms ranging from a few hundreds to a few thousands. In this paper, we introduce a semismooth Newton method that solves the dual problem of (NEDM). We prove that the method is quadratically convergent. We then present an application of the Newton method to NEDM with H -weights via majorization and an accelerated proximal gradient scheme. We demonstrate the superior performance of the Newton method over existing methods including the latest quadratic semi-definite programming solver. This research also opens a new avenue towards efficient solution methods for the molecular embedding problem.

Bin Wu, National University of Singapore (with Chao Ding, Defeng Sun, Kim-Chuan Toh)

The Moreau-Yosida regularization of the Ky Fan k -norm related functions

Matrix optimization problems (MOPs) involving the Ky Fan k -norm arise frequently in diverse fields such as matrix norm approximation, graph theory, and so on. In order to apply the proximal point algorithms to solve large scale MOPs involving the Ky Fan k -norm, we need to understand the first and second order properties of the Moreau-Yosida regularization of the Ky Fan k -norm function and the indicator function of its epigraph. As an initial step, we first study the counterparts of the vector k -norm related functions, including the metric projectors over the dual vector k -norm ball and the vector k -norm epigraph, and their directional derivatives and Fréchet differentiability. We then use these results to study the corresponding properties for the Moreau-Yosida regularization of the Ky Fan k -norm epigraph indicator function.

Renato Monteiro, Georgia Tech (with Benar Svaiter)

An accelerated hybrid proximal extragradient method for convex optimization and its implications to second-order methods

We present an accelerated variant of the hybrid proximal extragradient (HPE) method for convex optimization, referred to as the A-HPE method. Iteration-complexity results are established for the A-HPE method, as well as a special version of it, where a large stepsize condition is imposed. Two specific implementations of the A-HPE method are described in the context of a structured convex optimization problem whose objective function consists of the sum of a smooth convex function and an extended real-valued non-smooth convex function. In the first implementation, a generalization of a variant of Nesterov's method is obtained for the case where the smooth component of the objective function has Lipschitz continuous gradient. In the second one, an accelerated Newton proximal extragradient (A-NPE) method is obtained

for the case where the smooth component of the objective function has Lipschitz continuous Hessian. It is shown that the A-NPE method has a $\mathcal{O}(1/k^{7/2})$ convergence rate, which improves upon the $\mathcal{O}(1/k^3)$ convergence rate bound for another accelerated Newton-type method presented by Nesterov.

Constraint programming

Mon.3.H 3003A

Constraint programming standard and industrial applications

Organizer/Chair Narendra Jussien, École des Mines de Nantes · Invited Session

Roberto Castaneda Lozano, Swedish Institute of Computer Science (SICS) (with Mats Carlsson, Frej Drejhammar, Christian Schulte)

Robust code generation using constraint programming

Code generation in a compiler transforms an intermediate program representation into assembly code for a particular architecture. It has tremendous impact on the resulting code: optimal assembly code can be several times more efficient than naive assembly code. However, optimization techniques are typically not used for code generation as they are considered as non-scalable. Instead, traditional optimizing compilers compromise code quality by addressing code generation with heuristic algorithms and phase decomposition.

Two central phases in code generation are instruction scheduling and register allocation which are strongly interdependent. In this presentation, we introduce combinatorial models that naturally capture both phases. These models are easier to analyze and reuse than traditional heuristic algorithms. Then, we present an integrated model that captures the dependencies between phases and hence enables the generation of possibly optimal code. Finally, we illustrate why constraint programming with features such as flexible search and global constraints is a good candidate for robustly solving code generation problems.

Narendra Jussien, École des Mines de Nantes (with Jacob Feldman)

JSR331 – Standard for Java constraint programming API

JSR331 is a standard for Java Constraint Programming API that was initiated in August-2009 and had been approved by the Java Community Process (www.jcp.org) Executive Committee in February-2012. In this presentation we will describe the major concepts currently covered by the JSR331 and will provide examples of well-known constraint satisfaction and optimization problems implemented using the standard. We will demonstrate how a user may switch between different implementations of the JSR331 without any changes in the problem representation. We will share the JSR331 implementation experience and will discuss the future directions of the standardization process.

Abder Aggoun, KLS OPTIM (with Raphaël Martin, Ahmed Rhiat)

Modelling and solving a class of combinatorial problems in supply chain using the Choco constraint programming system

KLS OPTIM is an SME specialist in Logistic Optimization offering a complete suite of solutions. The main problems addressed are packing, pallet loading, optimization in distribution by minimizing the number of pallets, optimization of vehicle loading plans, optimization of assignment of containers in wagons, decision making applications. Most of the problems are known in the literature as bin packing problems. KLS OPTIM developed a set of dedicated business solvers. OptimPallet is powered by a 3D solver which consists of packing boxes of various sizes into available pallets in a way which optimizes the total number of pallets. OptimTruck proposes an optimal loading plan for each vehicle of the fleet company. OptimTrain deals with the operational planning of trains. The objective is to minimize the number of wagons while placing the maximum number of containers. The CP Engine Choco is a key component for modeling and solving packing problems. Rules2CP is a rule-based language compiler developed at INRIA. It makes possible to model packing rules into a concise formalism which is automatically translated into Choco programs.

Finance & economics

Mon.3.H 3027

Risk management in finance and insurance

Organizer/Chair Walter Farkas, University of Zurich, Department of Banking and Finance · Invited Session

Walter Farkas, University of Zurich, Department of Banking and Finance (with Pablo Koch-Medina, Cosimo-Andrea Munari)

Acceptability and risk measures: effectiveness, robustness and optimality

We discuss risk measures generated by general acceptance sets allowing for capital injections to be invested in a pre-specified eligible

asset. Risk measures play a key role when defining required capital for a financial institution. We address the three critical questions: when is required capital a well-defined number for any financial position? When is required capital a continuous function of the financial position? Can the eligible asset be chosen in such a way that for every financial position the corresponding required capital is lower than if any other asset had been chosen? Our discussion is not limited to convex or coherent acceptance sets and this generality opens up the field for applications to acceptance sets based both on Value-at-Risk and on Tail Value-at-Risk.

Cosimo-Andrea Munari, ETH Zurich (with Walter Farkas, Pablo Koch-Medina)

Risk measures and capital requirements with multiple eligible assets

We discuss risk measures associated with general acceptance sets for financial positions. Such risk measures represent the cost expressed as the minimum additional capital amount that, when invested in a pre-specified set of eligible assets, makes an unacceptable position acceptable. In contrast to earlier papers where the attention was focused on a single eligible asset, here we allow for multiple eligible assets. We show that the multiple eligible asset case can be reduced to the single asset case, provided that the set of acceptable positions can be properly enlarged. This is the case when it is not possible to make every financial position acceptable by adding a zero-cost portfolio of eligible assets. The results here simplify and generalize results of Frittelli and Scandolo from 2006 and of Artzner, Delbaen and Koch-Medina from 2009. However, in contrast to the literature, we do not impose any coherence or convexity requirements on the acceptance sets.

William Pouliot, University of Birmingham

Value-at-Risk

The implementation of appropriate statistical techniques (backtesting) for monitoring conditional VaR models is the mechanism used by financial institutions to determine the severity of the departures of the VaR model from market results and, subsequently the tool used by regulators to determine the penalties imposed for inadequate risk models. So far, however, there has been no attempt to determine the timing of this rejection and with it to obtain some guidance regarding the cause of failure in reporting an appropriate VaR. This paper corrects this by proposing U -statistic type processes that extend standard CUSUM statistics widely employed for change-point detection. In contrast to CUSUM statistics these new tests are indexed by certain weight functions that enhance their statistical power to detect the timing of the market risk model failure. These tests are robust to estimation risk and can be devised to be very sensitive to detection of market failure produced early in the out-of-sample evaluation period, in which standard methods usually fail due to the absence of data.

Game theory

Mon.3.MA 043

Design of optimal mechanisms

Organizer/Chair Rudolf Müller, Maastricht University · Invited Session

Maria Polukarov, University of Southampton (with Nicholas R. Jennings, Victor Naroditskiy)

Optimal payments in dominant-strategy mechanisms for single-parameter domains

We study dominant-strategy mechanisms in allocation domains where agents have one-dimensional types and quasi-linear utilities. Taking an allocation function as an input, we present an algorithmic technique for finding optimal payments in a class of mechanism design problems, including utilitarian and egalitarian allocation of homogeneous items with nondecreasing marginal costs. Our results link optimality of payment functions to a geometric condition involving triangulations of polytopes. When this condition is satisfied, we constructively show the existence of an optimal payment function that is piecewise linear in agent types.

Mingyu Guo, University of Liverpool (with Vincent Conitzer, Amy Greenwald, Nicholas Jennings, Victor Naroditskiy)

Computationally feasible automated mechanism design: General approach and a case study on budget-balanced and nearly efficient randomized mechanisms

In automated mechanism design, the idea is to computationally search through the space of feasible mechanisms, rather than to design them analytically by hand. Unfortunately, the most straightforward approach to automated mechanism design does not scale to large instances, because it requires searching over a very large space of possible functions. We describe an approach to automated mechanism design that is computationally feasible. Instead of optimizing over all feasible mechanisms, we carefully choose a parameterized subfamily of mechanisms. Then we optimize over mechanisms within this family, and analyze whether and to what extent the resulting mechanism is suboptimal outside the subfamily.

We demonstrate the usefulness of our approach with a case study on budget-balanced and nearly efficient mechanisms. Faltings [05] proposed the idea of excluding one agent uniformly at random from the decision and making him the residual claimant. We show that Faltings' mechanism can be generalized to a parameterized subfamily of mechanisms. In two example scenarios, by optimizing within the above subfamily, we are able to find mechanisms that are budget-balanced and nearly efficient.

Konrad Mierendorff, University of Zürich (with Yeon-Koo Che, Jinwoo Kim)

Generalized reduced-form auctions: A network-flow approach

We develop a network-flow approach for characterizing interim-allocation rules that can be implemented by ex post allocations. The network method can be used to characterize feasible interim allocations in general multi-unit auctions where agents face hierarchical capacity constraints. We apply the method to solve for an optimal multi-object auction mechanism when bidders are constrained in their capacities and budgets.

Global optimization

Mon.3.H 2053

Algorithms and relaxations for nonconvex optimization Problems

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Bissan Ghaddar, Department of National Defence (with Juan Vera)

A global optimization approach for binary polynomial programs

In this talk, we present branch-and-dig, an algorithm to find global solutions for binary polynomial programming problems. Inequality generating techniques based on lift-and-project relaxations are developed for binary polynomial problems which can help speed up the branch-and-bound process by improving the bounds at each node, thus reducing the number of nodes of the tree. Computational results for small test problems of degree three are given. In the computational study, we investigate the performance of different branching rules and the impact of the dynamic inequality generation scheme.

Takahito Kuno, University of Tsukuba (with Tomohiro Ishihama)

A class of convergent subdivision strategies in the conical algorithm for concave minimization

We present a new proof of the convergence of the conical algorithm for concave minimization under a pure ω -subdivision strategy. In 1991, Tuy showed that the conical algorithm with ω -subdivision is convergent if a certain kind of nondegeneracy holds for sequences of nested cones generated in the process of the algorithm. Although the convergence has already been proven in other ways, it still remains an open question whether the sequences are nondegenerate or not. In this talk, we introduce a weaker condition of nondegeneracy, named *pseudo-nondegeneracy*, and show that the conical algorithm with ω -subdivision converges as long as the pseudo-nondegeneracy holds for sequences of nested cones generated by the algorithm. We also show that every sequence generated by the algorithm is pseudo-nondegenerate. The pseudo-nondegeneracy is not only a useful condition for proving the convergence, but suggests a possible class of convergent subdivision strategies.

Achim Wechsung, Massachusetts Institute of Technology (with Paul Barton)

Improving relaxations of implicit functions

A factorable function $\mathbf{f} : Y \rightarrow \mathbb{R}^m$, $Y \subset \mathbb{R}^n$ can be represented as a DAG. While it is natural to construct interval extensions of factorable functions, the DAG representation has been shown to also enable the backward propagation of interval bounds on the function's range, i.e., to provide an enclosure of the intersection of Y with the function's pre-image. One application is to eliminate points in the domain where no solution of $\mathbf{f}(\mathbf{y}) = \mathbf{0}$ exists. This idea can be extended to the case of constructing convex relaxations of implicit functions. When $n > m$, it is possible to partition Y into $X \subset \mathbb{R}^m$ and $P \subset \mathbb{R}^{n-m}$. Assuming that X and P are intervals and that there exists a unique $\mathbf{x} : P \rightarrow X$ such that $\mathbf{f}(\mathbf{x}(\mathbf{p}), \mathbf{p}) = \mathbf{0}$, it is then possible to construct relaxations of the implicit function \mathbf{x} using the DAG representation of \mathbf{f} , backward propagation and generalized McCormick relaxation theory. These relaxations can be used to initialize other methods that improve relaxations of implicit functions iteratively.

Implementations & software

Mon.3.H 1058

MILP software I

Organizer/Chair Thorsten Koch, ZIB · Invited Session

Dieter Weninger, FAU-Erlangen (with Gerald Gamrath, Thorsten Koch, Alexander Martin, Matthias Miltenberger)

SCIP preprocessing for MIPs arising in supply chain management

Supply Chain Management (SCM) deals with the combination of procurement, production, storage, transport and delivery of commodities. Problems of this kind occur in different industry branches. Since the integrated planning of these processes contain a high potential for optimization, it is of great importance for the efficiency of a related company. The method of choice to find optimal solutions for SCM problems is mixed integer programming. However, there are big challenges to overcome due to the very detailed and therefore large models. One way to reduce the large models is to perform an extensive preprocessing. We show preprocessing algorithms which decisively help reducing and solving the problems. The implementations of the preprocessing algorithms are done within the non-commercial mixed integer programming solver SCIP.

Philipp Christophel, SAS Institute Inc. (with Amar Narisetty, Yan Xu)

Research topics of the SAS MILP solver development team

This talk will give an overview of current research interests of the SAS MILP solver development team. The focus will be on the use and customization of simplex algorithms inside MILP solvers. Other topics will be branching, cutting planes and primal heuristics.

Gerald Gamrath, Zuse Institute Berlin

The SCIP Optimization Suite 3.0 - It's all in the bag!

We present the latest release of the SCIP Optimization Suite, a tool for modeling and solving optimization problems. It consists of the modeling language ZIMPL, the LP solver SoPlex, and the constraint integer programming framework SCIP.

Besides being one of the fastest MIP solvers available in source code, SCIP can also be used as a branch-cut-and-price framework. Furthermore, SCIP is able to solve a much wider range of optimization problems including pseudo-boolean optimization, scheduling, and non-convex MINLP. Its plugin-based design allows to extend the framework to solve even more different kinds of problems and to customize the optimization process.

We report on current developments and new features of the SCIP Optimization Suite 3.0 release, including enhanced MINLP support, a framework to parallelize SCIP and the new exact solving capabilities for MIPs.

Integer & mixed-integer programming

Mon.3.H 2013

MILP formulations II

Chair Rui Oliveira, IST/ID

Stefan Schmieder, FAU Erlangen-Nürnberg (with Alexander Martin)

Optimizing life cycle costs for buildings

Life cycle oriented optimization of infrastructures is concerned with the automatic planning of buildings, plants etc from the first line of drawing up to the final polishing of the windows. Turning this into a mathematical model results in a very complex problem. There are a vast number of influencing factors, which have to be considered and which have a strong impact on the final solutions. In the case of our application scenario, namely public buildings, this leads to huge mixed-integer linear programs. To develop solution methods for the application we decompose the problem into subproblems, which stay hard to solve individually, too. In the buildings scenario we present the room allocation problem and take a closer look at different aspects like the planning of escape routes which we formulate as a graph theoretical problem and analyze its complexity. Moreover we present a mathematical model and solution methods for the complete room allocation problem.

Ali Fattahi, KOC University (with Erfan Sadeqi Azer, Hosein Shams Shemirani, Metin Turkey)

A novel integer programming formulation for U-shaped line balancing problems type-1

U-shaped production lines are regarded as an efficient configuration in Just-In-Time manufacturing and attract the attention from academic and industry. Balancing the workload in these lines is an unsolved problem and significant research has been done within the past two decades. So far, only a few optimization models have been developed and researchers and practitioners use these models to solve different variants of the balancing problem in U-shaped production lines. We present a novel integer programming formulation for U-shaped line balancing problems (type-1), where the cycle time is given and the aim is

to minimize number of utilized stations. This new formulation has been tested on all of the benchmarking problems in literature and a paired t -test is also applied to provide a comparative analysis with the existing models. The analysis of the results shows that this novel integer programming formulation leads to significant improvement over the other models.

Rui Oliveira, IST/ID (with Ana Catana)

Models for school networks planning

School network planning can be formulated as a multi-facility location problem, and these formulations are reviewed in this paper. In practice, however, decisions on where to build new schools or to close/convert existing education facilities have to take into account numerous (conflicting) factors of different nature (social, political, pedagogical, financial, etc.) and various stakeholders with contrasting viewpoints and objectives. This leads to a fluid decision context for which such a normative approach has been recognized to have limitations to effective decision support. An alternative framework that nicely fits the ill-structured nature of the decision context, adopting a more descriptive/prescriptive approach, was developed for school network planning at municipal level in Portugal and is reported in this paper. This includes education demand forecasting based on demographic projection models, coupled with strategic options derived from urban and regional plans, leading to geographic-based education services demand-supply balancing analysis.

Integer & mixed-integer programming

Mon.3.H 2032

Trends in mixed integer programming I

Organizers/Chairs Andrea Lodi, University of Bologna; Robert Weismantel, ETH Zurich · Invited Session

Giacomo Nannicini, Singapore University of Technology and Design (with Gérard Cornuéjols, Francois Margot)

On the safety of Gomory cut generators

Gomory mixed-integer cuts are one of the key components in branch-and-cut solvers for mixed-integer linear programs. The textbook formula for generating these cuts is not used directly in open-source and commercial software due to the limited numerical precision of the computations: Additional steps are performed to avoid the generation of invalid cuts. This paper studies the impact of some of these steps on the safety of Gomory mixed-integer cut generators. As the generation of invalid cuts is a relatively rare event, the experimental design for this study is particularly important. We propose an experimental setup that allows statistically significant comparisons of generators. We also propose a parameter optimization algorithm and use it to find a Gomory mixed-integer cut generator that is as safe as a benchmark cut generator from a commercial solver even though it rejects much fewer cuts.

Utz-Uwe Haus, IFOR, ETH Zürich (with Frank Pfeuffer)

Split cuts for robust and generalized mixed-integer programming

Robust Mixed-Integer optimization problems are conventionally solved by reformulation as non-robust problems. We propose a direct method to separate split cuts for robust mixed-integer programs with polyhedral uncertainty sets, for both worst-case as well as best-case robustness. The method generalizes the well-known cutting plane procedure of Balas. Computational experiments show that applying cutting planes directly is favorable to the reformulation approach. It is thus viable to solve robust MIP problems in a branch-and-cut framework using a Generalized Linear Programming oracle.

Oktay Güntük, IBM Research (with Sanjeeb Dash, Neil Dobbs, Tomasz Nowicki, Grzegorz Swirszcz)

Lattice-free sets, branching disjunctions, and mixed-integer programming

We study the relationship between valid inequalities for mixed-integer sets, lattice-free sets associated with these inequalities and structured disjunctive cuts, especially the t -branch split cuts introduced by Li and Richard (2008). By analyzing n -dimensional lattice-free sets, we prove that every facet-defining inequality of the convex hull of a mixed-integer polyhedral set with n integer variables is a t -branch split cut for some positive integer t . Moreover, this number t does not depend on the data defining the polyhedral set and is bounded by a function of the dimension n only. We use this result to give a finitely convergent cutting-plane algorithm to solve mixed-integer programs. We also show that the minimum value t , for which all facets of polyhedral mixed-integer sets with n integer variables can be expressed as t -branch split cuts, grows exponentially with n . In particular, when $n = 3$, we observe that not all facet-defining inequalities are 6-branch split cuts.

Integer & mixed-integer programming

Mon.3.MA 042

Linear optimization

Chair Angelo Sifaleras, University of Macedonia

Sergei Chubanov, University of Siegen

An improved polynomial relaxation-type algorithm for linear programming

To find a solution of a system of linear inequalities, the classical relaxation method projects the current point, at every iteration, onto a hyperplane defined by a violated constraint. The constructed sequence converges to a feasible solution. It is well known that the method is not polynomial. One of the reasons for this is that each iteration considers only one violated constraint among the original constraints of the system. Unlike the relaxation method, each iteration of our algorithm considers an appropriate nonnegative linear combination of the inequalities. The algorithm runs in $O(n^3 L_{\min})$ time where n is the number of variables and L_{\min} is the minimum binary size of a feasible solution. In particular, the algorithm either finds a nonnegative solution of a system of linear equations or proves that there are no 0, 1-solutions in $O(n^4)$ time. This theoretical estimate is less by the factor of n^2 than that of our previous algorithm.

Roland Wunderling, IBM

The kernel simplex method

The Simplex Method has stopped seeing major computational advances for years, yet it remains the most widely used algorithm for solving LPs; in particular the dual Simplex algorithm is used for MIP because of its warm-start capabilities. State-of-the-art MIP solvers use branch-and-cut algorithms, but the standard dual simplex algorithm only addresses the branching aspect of it. When cuts are added usually a fresh factorization of the basis matrix is needed which greatly reduces true warm-start support. Using a row basis or dualization can mitigate the issue, but this is only efficient for models with more rows than columns.

In this talk we introduce a new simplex algorithm, the kernel simplex method (KSM), which defines a kernel instead of a basis as the central data structure. KSM, provides full warm-starting functionality for row and column additions or deletions. We describe the algorithm and differentiate its computational properties against the traditional simplex method. Further, we show how KSM unifies primal and dual algorithms into one symmetric algorithm, thus matching duality theory much better than the traditional methods.

Angelo Sifaleras, University of Macedonia (with Nikolaos Samaras)

Exterior point simplex-type algorithms for linear and network optimization problems

The linear problem is one of the most useful and well-studied optimization problems, which is widely used in several areas of science. Lots of real world problems can be formulated as linear programs. The popularity of linear programming can be attributed to many factors such as the ability to model large problems, and the ability to solve large problems in a reasonable amount of time. Many algorithms have been invented for the solution of a linear program. The majority of these algorithms belong to two main categories: (i) Simplex-type or pivoting algorithms and (ii) interior-point methods (IPMs). All the algorithms presented in this paper belong to the first category, except one that belongs to both categories. The first exterior point simplex type algorithm (EPSA) was originally developed by Paparrizos for the assignment problem. EPSA constructs two paths to the optimal solution. One path consists of basic but not feasible solutions, while the second path is feasible. The key idea behind EPSA is that making steps in directions that are linear combinations of attractive descent direction can lead to faster convergence than that achieved by classic simplex type algorithms.

Life sciences & healthcare

Mon.3.H 2033

Therapy planning

Chair Laurenz Göllmann, Münster - University of Applied Sciences

Åsa Holm, Linköping University (with Åsa Carlsson Tedgren, Torbjörn Larsson)

A new optimization model for brachytherapy dose plans

There are many types of radiotherapy, brachytherapy is one such. As a part of treatment planning, a dose plan needs to be constructed, this decides where and for how long to irradiate. Optimization of dose plans for brachytherapy is still an area that is relatively unexplored, and since the treatment is quite different, models used for external radiotherapy are not directly applicable. In this talk I will highlight the most important differences and then present the model we have formulated

and some results from our tests. Our model differs from others used in the brachytherapy field by more directly including dosimetric indices.

Rasmus Bokrantz, KTH Royal Institute of Technology / RaySearch Laboratories

Multi-criteria optimization for volumetric-modulated arc therapy by convex decompositions

Volumetric-modulated arc therapy (VMAT) is a technique for rotational radiation therapy that has gained widespread clinical use due to its ability of improving delivery efficiency without compromising treatment quality. Treatment planning for VMAT is a challenging multi-criteria decision problem due to a high-dimensional trade-off between tumor coverage and sparing of healthy structures in the vicinity of the target volume. Here, an approach to multi-criteria VMAT optimization is presented that relies on two convex decompositions of an initially nonconvex problem formulation. An infeasible relaxation with the elements of the energy fluence vector as variables is first used to define a global trade-off between conflicting objectives. The solution to the relaxed problem is subsequently converted into a deliverable VMAT plan. A feasible restriction with segment weights as variables is finally used to evaluate deliverable solutions in its neighborhood. The practical value of the presented method is discussed in view of comparative results with a commercially available single-objective method.

Laurenz Göllmann, Münster - University of Applied Sciences (with Helmut Maurer)

Combination therapy considered as a multiple delayed optimal control problem

We consider optimal control problems with multiple time delays in state and control and present an enhanced form of Pontryagin's minimum principle as well as a numerical discretization method.

Let $x(t) \in \mathbb{R}^n$ denote the state and $u(t) \in \mathbb{R}^m$ denote the control of a system at time t . Time delays for x and u are given by a vector (r_1, \dots, r_d) . The problem for two delays has been investigated earlier in [GöllmannKernMaurer09]. We now present a generalization in form of necessary conditions for the problem with multiple delays. We finally optimize a combination therapy by a model of the innate immune response with a delayed antibody production and a retarded drug action.

Logistics, traffic, and transportation

Mon.3.H 0106

Applications in transportation problems

Chair Paola Pellegrini, IFSTTAR - Univ. Lille Nord de France

Joshua Magbagbeola, Joseph Ayo Babalola University, Ikeji-Arakeji (with Samuel Awoniyi, Eunice Magbagbeola)

Operations research approach to enhancing enterprise through alliances: A case study of Mowe Town, Ogun State, Nigeria

Small firm sub-sector has the potential to reduce poverty and unemployment in Nigeria. However, in the face of global competition, market uncertainties and rapid technological changes, it is necessary to assist firms, particularly small enterprise to access information that can build their business competencies to create income and employment generation opportunities. Through in-depth recourse to existing theories and empirical literature on factors that explain firm growth, the study identifies business competencies, derived through inter-firm alliances, as determinants of enterprise performance. The study establishes that the size of the firm influences the choice of business association among manufacturing enterprises in Nigeria. It is further noted that the decision to join a business association is positively related to the ages of the entrepreneur and enterprise. The study recommends incentive mechanisms that encourage business associations among small enterprise.

Hidetoshi Miura, Nanzan University (with Toshio Nemoto)

Comparative study of reduced total travel times in check-pattern and hierarchical express systems

Express-service stop pattern on railway is an important factor to shorten travel time for long-distance users. However, it is difficult for trunk line to run enough expresses during rush hours by reason of track capacity for safety. Lack of track capacity gives trains few occasions to pass others. This study calculates reduced total travel time by expresses to compare three limited-service stop patterns: single express pattern system, check-pattern system, and hierarchical system. The hierarchical system gives stops of upper type of express to include all stops of lower expresses. The check-pattern system does not allow sharing stops between different types of expresses. Though the check-pattern system does not become common, it will give more expresses than the hierarchical system during high train density. Some simple assumptions in this railway model facilitate analytical representation to locate limited-service stops for maximizing reduced travel times. We will de-

scribe the optimal limited-service stop patterns and the optimal number of stops of three systems.

Paola Pellegrini, IFSTTAR - Univ. Lille Nord de France (with Grégory Marlière, Joaquin Rodriguez)
Exact models for the real time railway traffic management problem: tackling perturbed traffic considering real junction details

A railway traffic management problem appear when trains are delayed: the originally planned routing and scheduling become infeasible. This problem must be solved in real time (i.e., in a short time) by finding a minimum cost feasible routing and scheduling of trains on a network. Solution cost is assessed in terms of either punctuality or fluidification. In the literature, this problem, known as "real time railway traffic management problem", is typically tackled with heuristic algorithms. Optimal approaches appear only when few network details are considered. We propose two mixed-integer linear programming models which consider real railway junctions details. They differ in the computation of solution cost. We test the two models on real instances representing three complex junctions: Pierrefitte-Gonesse (France), Lille Flandres station (France), and Utrecht Den Bosh line (Netherlands). In all cases, computation time is very short. Interestingly, different junctions are differently complex for the two models. We will devote further research to the explanation of these differences, and to the identification of effective valid inequalities.

Logistics, traffic, and transportation

Mon.3.H 0111

Network problems

Chair Kwong Meng Teo, National University of Singapore

Thomas Kalinowski, Universität Rostock (with Natasha Boland, Hamish Waterer, Lanbo Zheng)

Scheduling arc outages in networks to maximize total flow over time

We present a problem arising in the annual maintenance planning process for the Hunter Valley Coal Chain which has the potential to be applied in a variety of transportation network contexts. The problem consists of sending flow from a source s to a sink t in each time period $1, 2, \dots, T$. An additional difficulty comes from the fact that some arcs in the network have associated jobs that have to be scheduled and during processing of a job the corresponding arc is not available. In the talk we discuss some complexity results (NP-hardness of the single node case, efficiently solvable special cases), a MIP model and some computational results on real world data sets.

Daniel Ferber, Petrobras - Petróleo Brasileiro S/A

Incorporating temporal in-transit inventory into linear programming network flow models

We consider a network flow model to support planning the pipeline supply chain of oil refined commodities. The traditional supply chain models discussed in literature do not regard temporal aspects of in-transit inventory. Hence, they may underestimate the utilization of pipelines and risk proposing impracticable solutions. We take into account a multi-product, multi-period network with production, demand and storage on facilities, through a pure linear programming model. For a better approximation of pipeline utilization rates, we incorporate temporal aspects of transit in-transit inventory on their path between facilities. Without resorting to integer variables, we extend the model to estimate on each time slot dynamic flow capacities which depend on the current in-transit inventory configuration. Further, pipelines are allowed to reverse their flow. A result for a real world industry scenario is compared in order to attest benefits of our model.

Kwong Meng Teo, National University of Singapore (with Trung Hieu Tran)

Solving network flow problems with general non-separable convex costs using a two-phase gradient projection algorithm

Network flow problems are often encountered in practical applications such as multi-commodity flows, traffic assignment and telecommunications problems. Simpler problems such as those with quadratic costs are often solved using general solvers such as CPLEX, while more realistic but difficult ones with generalized non-separable convex costs would require specialized network optimization algorithms where speed of convergence and problem size becomes challenging issues in practice. We propose a two-phase gradient projection algorithm to bridge this gap. The proposed algorithm is designed to address the weaknesses of traditional gradient projection approaches reported in the literature, including choice of step size, speed of convergence and ease of implementation. Furthermore, the algorithm has been implemented as a toolbox riding on general solvers such as CPLEX for easy adoption and to handle industrial size problems. We evaluate and compare the performance of the proposed algorithm with other approaches under common network flow scenarios such as (i) integral or continuous flows and (ii) explicit or non-explicit objective.

Mixed-integer nonlinear programming

Mon.3.MA 005

Tight relaxations

Organizer/Chair Stefan Vigerske, GAMS Software GmbH · Invited Session

Thomas Lehmann, Siemens Corporate Technology

On the efficient construction of disjunctive cutting planes for mixed-integer quadratic optimization problems

We present an algorithmic procedure for efficiently constructing disjunctive cutting planes for non-basic solutions or proving their non-existence. The method extends an algorithm proposed by Perregaard and Balas, such that it is applicable for non-basic solutions, e.g., obtained from the continuous relaxation of a mixed-integer quadratic program.

We also present preliminary numerical results for test problems, that arise within MIQP-based solution methods for mixed-integer nonlinear optimization problems, such as MISQP proposed by Exler, Lehmann and Schittkowski. The results indicate the potential of the proposed cut generator, but they also stress the necessity of an advanced cut management.

Dennis Michaels, ETH Zurich (with Martin Ballerstein, Robert Weismantel)

The convex hull of vectors of functions

A challenging task in global optimization is to construct tight convex relaxations that provide reasonably globally valid bounds on a mixed-integer nonlinear program (MINLP). For a general MINLP, convex relaxations are usually obtained by replacing each non-linearity by convex under- and concave overestimators. The mathematical object studied to derive such estimators is given by the convex hull of the graph of the function over the relevant domain. To derive improved relaxations, we consider a finite set of given functions as a vector-valued function and study the convex hull of its graph. We establish a link between such a convex hull object and the convex hulls of the graphs of a certain family of real-valued functions. This link can be used to define improved relaxations. We especially focus on small sets of well-structured univariate functions. Numerical examples are presented demonstrating the impact of this concept.

Ambros Gleixner, Zuse Institute Berlin (ZIB) (with Timo Berthold, Stefan Weltge)

Rapid optimality-based bound tightening

Optimality-based bound tightening (OBBT) is a well-known, simple, yet computationally expensive procedure to reduce variable domains of mixed-integer nonlinear programs (MINLPs) by solving a series of auxiliary linear programs (LPs). We present techniques to reduce the computational effort incurred by OBBT and exploit dual information from the LP solutions during a subsequent branch-and-bound solution process. We evaluate the performance impact of these techniques using an implementation within the MINLP solver SCIP.

Multi-objective optimization

Mon.3.H 1029

Multi-objective optimization

Organizer/Chair Emilio Carrizosa, Universidad de Sevilla · Invited Session

Antonio Flores-Tlacuahuac, Universidad Iberoamericana (with Morales Pilar, Zavala Victor)

An utopia-tracking approach to multiobjective predictive control

We propose a multiobjective strategy for model predictive control (MPC) that we term utopia-tracking MPC. The controller minimizes, in some norm, the distance of its cost vector to that of the unreachable steady-state utopia point. Stability is ensured by using a terminal constraint to a selected point along the steady-state Pareto front. One of the key advantages of this approach is that multiple objectives can be handled systematically without having to compute the entire Pareto front or selecting weights. In addition, general cost functions (i.e., economic, regularization) can be used.

Włodzimirz Ogryczak, Warsaw University of Technology

Fair multiobjective optimization: Models and techniques

In systems which serve many users there is a need to respect some fairness rules while looking for the overall efficiency, e.g., in network design one needs to allocate bandwidth to flows efficiently and fairly, in location analysis of public services the clients of a system are entitled to fair treatment according to community regulations. This leads to concepts of fairness expressed by the equitable multiple objective optimization. The latter is formalized with the model of multiple objective optimization of tail averages and the Lorenz order enhancing the Pareto dominance concept. Due to the duality theory, the order is also equivalent to the second order stochastic dominance representing multiple objective optimization of the mean shortages (mean below-target deviations). Despite equivalent, two orders lead to different computational models though both based on auxiliary linear inequalities and criteria.

Moreover, the basic computational models can be differently enhanced. We analyze advantages of various computational models when applied to linear programming and mixed integer programming problems of fair optimization.

Kai-Simon Goetzmann, TU Berlin (with Christina Büsing, Jannik Matuschke, Sebastian Stiller)

Compromise solutions

The most common concept in multicriteria optimization is Pareto optimality. However, in general the number of Pareto optimal solutions is exponential. To choose a single, well-balanced Pareto optimal solution, Yu [1973] proposed compromise solutions. A compromise solution is a feasible solution closest to the ideal point. The ideal point is the component-wise optimum over all feasible solutions in objective space. Compromise solutions are always Pareto optimal. Using different weighted norms, the compromise solution can attain any point in the Pareto set. The concept of compromise solutions (and the slightly more general reference point methods) are widely used in state-of-the-art software tools. Still, there are very few theoretical results backing up these methods.

We establish a strong connection between approximating the Pareto set and approximating compromise solutions. In particular, we show that an approximate Pareto set always contains an approximate compromise solution. The converse is also true if we allow to substitute the ideal point by a sub-ideal reference point. Compromise solutions thus neatly fit with the concept of Pareto optimality.

Nonlinear programming

Mon.3.H 0107

Methods for nonlinear optimization III

Chair Masoud Ahoosh, University of Vienna

Yuan Shen, Nanjing University (with Bingsheng He)

New augmented Lagrangian-based proximal point algorithms for convex optimization with equality constraint

The Augmented Lagrangian method (ALM) is a classic and efficient method for solving constrained optimization problem. It decomposes the original problem into a series of easy-to-solve subproblems to approach the solution of the original problem. However, its efficiency is still, to large extent, dependent on how efficient the subproblem can be solved. In general, the accurate solution of the subproblem can be expensive to compute, hence, it is more practical to relax the subproblem to make it easy to solve. When the objective has some favorable structure, the relaxed subproblem can be simple enough to have a closed form solution. Therefore, the resulting algorithm is efficient and practical for the low cost in each iteration. However, compared with the classic ALM, this algorithm can suffer from the slow convergence rate. Based on the same relaxed subproblem, we propose several new methods with faster convergence rate. We also report their numerical results in comparison to some state-of-the-art algorithms to demonstrate their efficiency.

Mehiddin Al-Baali, Sultan Qaboos University (with Mohamed Al-Lawatia)

Hybrid damped-BFGS/Gauss-Newton methods for nonlinear least-squares

The damped-technique in the modified BFGS method of Powell [1978] for constrained optimization will be extended to the hybrid BFGS/Gauss-Newton methods for unconstrained nonlinear least squares. It will be shown that this extension maintains the useful convergence properties of the hybrid methods and improves their performance substantially in certain cases. The analysis is based on a recent proposal for using the damped-technique when applied to the Broyden family of methods for unconstrained optimization, which enforces safely the positive definiteness property of Hessian approximations.

Masoud Ahoosh, University of Vienna (with Nosratipour Hadi, Amini Keywan)

An improved nonmonotone technique for both line search and trust-region frameworks

The nonmonotone iterative approaches are efficient techniques for solving optimization problems avoiding a monotone decrease in the sequence of function values. It has been believed that the nonmonotone strategies not only can enhance the likelihood of finding the global optimum but also can improve the numerical performance of approaches. Furthermore, the traditional nonmonotone strategy contains some disadvantages encountering with some practical problems. To overcome these drawbacks, some different nonmonotone strategies have proposed with more encouraging results. This study concerns with explorations on reasons of disadvantages of the traditional nonmonotone technique and introduce a variant version which mostly avoids the drawbacks of original one. Then we incorporate it into both line search and trust-region frameworks to construct more reliable approaches. The global convergence to first-order and second-order stationary points

are investigated under some classical assumptions. Preliminary numerical experiments indicate the efficiency and the robustness of the proposed approaches for solving unconstrained nonlinear optimization.

Nonlinear programming

Mon.3.H 0110

Nonlinear optimization III

Organizers/Chairs Frank E. Curtis, Lehigh University; Daniel Robinson, Johns Hopkins University · Invited Session

Mikhail Solodov, IMPA (with Damian Fernandez)

Convergence properties of augmented Lagrangian methods under the second-order sufficient optimality condition

We establish local convergence and rate of convergence of the classical augmented Lagrangian algorithm under the sole assumption that the dual starting point is close to a multiplier satisfying the second-order sufficient optimality condition (SOSC). No constraint qualifications of any kind are needed. Previous literature on the subject required, in addition, the linear independence constraint qualification and either strict complementarity or a stronger version of SOSC. Using only SOSC, for penalty parameters large enough we prove primal-dual Q -linear convergence rate, which becomes superlinear if the parameters are allowed to go to infinity. Both exact and inexact solutions of subproblems are considered. In the exact case, we further show that the primal convergence rate is of the same Q -order as the primal-dual rate. Previous assertions for the primal sequence all had to do with the weaker R -rate of convergence and required the stronger assumptions cited above. Finally, we show that under our assumptions one of the popular rules of controlling the penalty parameters ensures they stay bounded.

Frank E. Curtis, Lehigh University (with James Burke, Hao Wang)

Infeasibility detection in nonlinear optimization

Contemporary numerical methods for nonlinear optimization possess strong global and fast local convergence guarantees for feasible problems under common assumptions. They also often provide guarantees for (eventually) detecting if a problem is infeasible, though in such cases there are typically no guarantees of fast local convergence. This is a critical deficiency as in the optimization of complex systems, one often finds that nonlinear optimization methods can fail or stall due to minor constraint incompatibilities. This may suggest that the problem is infeasible, but without an infeasibility certificate, no useful result is provided to the user. We present a sequential quadratic optimization (SQO) method that possesses strong global and fast local convergence guarantees for both feasible and infeasible problem instances. Theoretical results are presented along with numerical results indicating the practical advantages of our approach.

Figen Oztoprak, Northwestern University

Two-phase active set methods with applications to inverse covariance estimation

We present a semi-smooth Newton framework that gives rise to a family of second order methods for structured convex optimization. The generality of our approach allows us to analyze their convergence properties in a unified setting, and to contrast their algorithmic components. These methods are well suited for a variety of machine learning applications, and in this talk we give particular attention to an inverse covariance matrix estimation problem arising in speech recognition. We compare our method to state-of-the-art techniques, both in terms of computational efficiency and theoretical properties.

Nonlinear programming

Mon.3.H 0112

Unconstrained optimization I

Chair Roummel Marcia, University of California, Merced

Saman Babaie-Kafaki, Semnan University

A modification on the Hager-Zhang conjugate gradient method

Conjugate gradient (CG) methods comprise a class of unconstrained optimization algorithms characterized by low memory requirements and strong global convergence properties which made them popular for engineers and mathematicians engaged in solving large-scale unconstrained optimization problems. One of the efficient CG methods has been proposed by Hager and Zhang. Here, a singular value study is made in order to find lower and upper bounds for the condition number of the matrix which generates the search directions of the Hager-Zhang method. Then, based on the insight gained by our analysis, a modified version of the Hager-Zhang method is proposed using an adaptive switch form the Hager-Zhang method to the Hestenes-Stiefel method, when the mentioned condition number is large. It can be shown that if the line search fulfills the strong Wolfe conditions, then the

proposed method is globally convergent for uniformly convex objective functions. Numerical experiments on a set of unconstrained optimization test problems of the CUTer collection demonstrate the efficiency of the suggested adaptive CG method in the sense of the performance profile introduced by Dolan and Moré.

Tove Odland, Royal Institute of Technology (with Anders Forsgren)

On the relationship between quasi-Newton methods and the conjugate

It is well known that a Quasi-Newton method using any well-defined update from the Broyden class of updates and the conjugate gradient method produce the same iterates on a quadratic objective function with positive-definite Hessian. In this case both methods produce conjugate directions with respect to the Hessian. This equivalence does not hold for any quasi-Newton method. We discuss more precisely what the updates in a Quasi-Newton method need satisfy to give rise to this behavior.

Roumml Marcia, University of California, Merced (with Jennifer Erway)

Limited-memory BFGS with diagonal updates

We investigate a formula to solve limited-memory BFGS quasi-Newton Hessian systems with full-rank diagonal updates. Under some conditions, the system can be solved via a recursion that uses only vector inner products. This approach has broad applications in trust region and barrier methods.

Nonsmooth optimization

Mon.3.H 1012

Nonsmooth optimization in imaging sciences I

Organizer/Chair Gabriel Peyré, CNRS · Invited Session

Gabriel Peyré, CNRS (with Jalal Fadili, Hugo Raguet)

A review of proximal splitting methods with a new one

In the first part of this talk, I will review proximal splitting methods for the resolution of large scale non-smooth convex problems (see for instance [1, 2]). I will show how each algorithm is able to take advantage of the structure of typical imaging problems. In the second part of this talk I will present the Generalized Forward Backward (GFB) splitting method [3] that is tailored for the minimization of the sum of a smooth function and an arbitrary number of "simple" functions (for which the proximal operator can be computed in closed form). I will show on several imaging applications the advantage of our approach over state of the art proximal splitting schemes. Demos and codes for these proximal splitting schemes can be obtained by visiting www.numerical-tours.com.

- [1] P. L. Combettes and J.-C. Pesquet, "Proximal splitting methods in signal processing", 2011.
- [2] A. Beck and M. Teboulle, "Gradient-Based Algorithms with Applications in Signal Recovery Problems", 2010.
- [3] H. Raguet, J. Fadili and G. Peyré, "Generalized Forward-Backward Splitting", preprint HAL-00613637.

Thomas Pock, Graz University of Technology (with Karl Kunisch)

On parameter learning in variational models

In this work we consider the problem of parameter learning for variational image denoising models. We formulate the learning problem as a bilevel optimization problem, where the lower level problem is given by the variational model and the higher level problem is given by a loss function that penalizes errors between the solution of the lower level problem and the ground truth data. We consider a class of image denoising models incorporating a sum of analysis based priors over a fixed set of linear operators. We devise semi-smooth Newton methods to solve the resulting non-smooth bilevel optimization problems and show that the optimized image denoising models can achieve state-of-the-art performance.

Volkan Cevher, École Polytechnique Federale de Lausanne (with Anastasios Kyriillidis)

Nonconvex models with exact and approximate projections for constrained linear inverse problems

Many natural and man-made signals exhibit a few degrees of freedom relative to their dimension due to natural parameterizations or constraints. The inherent low-dimensional structure of such signals are mathematically modeled via combinatorial and geometric concepts, such as sparsity, unions-of-subspaces, or spectral sets, and are now revolutionizing the way we address linear inverse problems from incomplete data. In this talk, we describe a set of low-dimensional, non-convex models for constrained linear inverse problems that feature exact and epsilon-approximate projections in polynomial time. We pay particular attention to structured sparsity models based on matroids, multi-knapsack, and clustering as well as spectrally constrained models. We describe a hybrid optimization framework which explicitly leverages these non-convex models along with additional convex constraints

to improve recovery performance. We then analyze the convergence and approximation guarantees of our framework based on restrictions on the linear operator in conjunction with several well-known acceleration techniques, such as step-size selection, memory, splitting, and block coordinate descent.

Optimization in energy systems

Mon.3.MA 549

Optimisation models for renewables integration

Organizers/Chairs Rodrigo Moreno, Imperial College London; Luiz Barroso, PSR · Invited Session

Enzo Sauma, Pontificia Universidad Catolica de Chile (with Javier Contreras, David Pozo)

Transmission planning and generation response for integrating renewables

Using a Mixed Integer Linear Programming (MILP) model, we analyze the transmission planning decisions while characterizing the competitive interaction among generation firms whose decisions in generation capacity investments and production are affected by both the transmission investments and the market operation. We illustrate the model by means of the implementation of a stylized version of the transmission planning in the main Chilean network.

Álvaro Veiga, PUC-Rio (with Bianca Amaral, Bruno Fânseres, Lucas Freire, Delberis Lima, Alexandre Street)

Backing up wind power firm contract sales on hydro generation with stochastic optimization: A Brazilian case study

In this case study, a wind power producer (WPP) backs up a contract sell in the forward market on a small run-of-river hydro (SH) Genco production. The model determines the amount of SH participation and the WPP willingness to contract. To achieve this goal, a joint wind-inflow statistical model is used to simulate renewable resources consistently with a set of simulated scenarios of short-term prices provided by an independent dispatch simulation tool. Such methodology is able to couple both sets of independently simulated scenarios such that a joint contracting opportunity can be evaluated and optimized.

Rodrigo Moreno, Imperial College London (with Danny Pudjianto, Goran Strbac)

Transmission network operation and planning with probabilistic security to facilitate the connection of renewable generation

Current transmission networks are mainly operated and designed based on deterministic decision-making methods. Such methods do not take consideration of real outage risks of network components and therefore of actual benefits and costs of corrective control (or operational measures). This leads to over requirement of transmission capacity in planning timescales and significant constraints to access remote wind power in operational timescales. In this context, this presentation analyses various characteristics of a fully integrated economic and reliability probabilistic framework for network operation and planning that takes account of efficient operational measures to deliver network capacity to users. For the demonstrations, a new two-stage probabilistic optimisation model for the operational and planning problems is presented. The model is based on a Benders algorithm and is able to balance network utilisation/redundancy levels against the use of operational measures by minimising costs and risks in every operating condition. A novel contingencies-selection technique to identify the relevant outages and therefore lower the computational burden is also presented.

Optimization in energy systems

Mon.3.MA 550

Stochastic optimization for electricity production and trading

Organizer/Chair Raimund Kovacevic, University of Vienna · Invited Session

Densing Martin, Paul Scherrer Institute (with János Mayer)

Multistage stochastic optimization of power dispatch and multiperiod duality of CVaR

We consider cost-optimization models of power production in the context of mean-risk multi-stage stochastic optimization problems. We introduce the concept of occupation times to reduce the size of the scenario tree in a finite setting in time and states. In terms of financial risk measurement, we apply multiperiod extensions of the risk measure Conditional-Value-at-Risk (CVaR), which is widely used in applications due to its coherency properties. We show a time-consistent generalization to multiple periods that applies CVaR-like measures recursively over the time periods and compare with other extensions. In terms of modeling, we discuss how financial futures may reduce risk and how

demand can be incorporated in the proposed framework. Numerical results are presented.

Georg Pflug, U Vienna (with Raimund Kovacevic)

Stochastic bilevel programs with applications to electricity contracts

We describe a typical contracting situation for flexible energy contracts as a bilevel stochastic program: The upper level sets the price and the lower level sets the execution pattern. Bilevel programs are hard nonconvex global problems and typically no polynomial algorithms exist. We present however some solution algorithms, including stochastic quasigradient methods, penalty methods and line search methods.

We give illustrative examples for electricity swing option pricing, but remark that the very same type of problems appears in insurance pricing (adverse selection and moral hazard) as well as in terrorism modeling.

Bitu Analui, University of Vienna

Multistage stochastic optimization problems under model ambiguity

A multistage stochastic optimization problem with uncertainty about the underlying model is considered. In this paper and for the first time we introduce and develop an approach that explicitly takes into account the ambiguity in probability model for the real world class of multistage stochastic optimization problems where the robustness of the decisions are highly expected. This is done by developing the concept of ambiguity of dynamic trees for multistage stochastic optimization problems incorporating the results from multistage distance. In the presence model ambiguity one approach is to study a set of possible models in which the true model sits. In this line, we define this set as an ϵ -radius (for the given ϵ) ball around a reference measure P with respect to a multistage distance d and therefore robustify the original problem by a worst case approach with respect to this ambiguity neighborhood. This way we analyze the sensitivity with respect to model changes. For implementation, we consider an optimization horizon with weekly discretization, the uncertainty is the random behavior of electricity spot prices.

PDE-constrained opt. & multi-level/multi-grid meth.

Mon.3.MA 415

Numerical methods in shape and topology optimization

Organizer/Chair Antoine Laurain, TU Berlin · Invited Session

Kevin Sturm, WIAS (with Michael Hintermüller, Dietmar Hömberg)

Shape optimization for an interface problem in linear elasticity for distortion compensation

In this talk I will introduce a sharp interface model describing a workpiece made of steel. In the heat treatment of steel different phases e.g., martensite and pearlite can be produced in the workpiece. The goal of my work is to obtain a desired workpiece shape by controlling the final phase distribution. Therefore our control variables are sets and thus we have to consider a shape optimization problem. I will show how one can derive the shape derivative for this problem, which then can be used to solve the shape optimization problem approximately. Moreover, numerical results for different workpiece shapes in two dimensions will be presented.

Volker Schulz, University of Trier

On the usage of the shape Hessian in aerodynamic shape optimization

The talk demonstrates how approximations of the shape Hessian can be profitably used to accelerate shape optimization strategies significantly in the application field of aerodynamics. However, at least theoretically, the shape Hessian is of less advantage than usual Hessians - essentially because there does not yet exist a Taylor series expansion in terms of the shape Hessian, and it tends to be nonsymmetric. In this talk, a new view on the shape Hessian is proposed in terms of an appropriate distance measure. Furthermore consequences for numerical implementations are explained.

Robust optimization

Mon.3.H 3503

Extensions of robust optimization approaches

Chair Mohammad Mehdi Nasrabadi, Payam Noor University

Phantipa Thipwivatpotjana, Faculty of Science, Chulalongkorn University (with Weldon Lodwick)

Pessimistic, optimistic, and min-max regret approaches for linear programs under uncertainty

Uncertain data appearing as parameters in linear programs can be categorized variously. However, most theoretical approaches and mod-

els limit themselves to the analysis involving merely one kind of uncertainty within a problem. This paper presents reasonable methods for handling linear programs with mixed uncertainties which also preserve all details about uncertain data. We show how to handle mixed uncertainties which lead to optimistic, pessimistic, and minimax regret in optimization criteria.

Michael Römer, Martin-Luther-University Halle-Wittenberg

Linear optimization with variable parameters: Robust and generalized linear programming and their relations

In linear programming, it is usually assumed that the problem data is certain and fixed. In many real world situations, however, the parameters are subject to variation. In a pessimistic scenario, the variation is not controllable by the decision maker: This is the case for parameters affected by measurement errors or uncertainty. One way to deal with such a situation is to employ robust linear programming to obtain a solution that is feasible for all elements of a given parameter uncertainty set.

In an optimistic scenario, the variation can be controlled: Some coefficients may represent adjustable technical parameters or can be influenced by higher-level decisions. A possible approach to model this setting is generalized linear programming. In this approach, going back to early work of Dantzig and Wolfe, a solution is sought which is feasible for at least one parameter combination from a given variation set.

In this work, we provide a unified view of robust and generalized linear programs and their compact reformulations. We discuss the dual relation of both approaches and show how this duality may contribute to a deeper understanding and a mutual stimulation of both fields.

Mohammad Mehdi Nasrabadi, Payam Noor University

A fuzzy programming approach to robust optimization

A crucial feature of linear programming occurring in real-world applications is that all or some of parameters are uncertain. Robust optimization has attracted a great deal of attention to address this situation. We consider robust linear programs, where the parameters in the constraint matrix are uncertain but known to lie in a given deterministic uncertainty set. We present a fuzzy programming approach to soften the hard constraints of the robust optimization. In particular, given a feasible solution, we introduce a membership function for each constraint to indicate how much the constraint is violated in the worst-case. We characterize the three basic ingredients in fuzzy decision making, that are, fuzzy goal, fuzzy constraint, and fuzzy decision. We then present an algorithm for solving the robust linear program with softness constraints based on the well-known approach of Bellman and Zadeh (1970) in fuzzy programming. We show that the problem is efficiently solvable when the uncertain parameters are the ones considered by Bertsimas and Sim (2003).

Robust optimization

Mon.3.MA 004

Robust network optimization

Organizer/Chair Ebrahim Nasrabadi, Massachusetts Institute of Technology · Invited Session

Sebastian Stiller, TU Berlin (with Dimitris Bertsimas, Telha Claudio, Ebrahim Nasrabadi, Kai-Simon Goetzmann)

Robust network flows

This talk collects results on four different variants of robust network flows: the cost-robust counterpart, the strict robust counterpart, and the adjustable robust counterpart of the maximum network flow problem, and the robust flow-over-time problem. For all four models we consider scenario sets where at most a fixed number of coefficients in the input can change and all coefficients are limited within given intervals. The results on the cost-robust counterpart are derived in the form of a general result on cost-robust integer programs, in particular for those with TUM matrices. The strict robust network flow is shown to be polynomial time solvable but far too conservative. The (fractional) adjustable robust flow problem is shown to be NP-hard. It lacks a lot of the properties of nominal network flows. Nevertheless, it exhibits a variant of the min-cut-max-flow property, which we prove via a game theoretic argument. We also describe some efficiently solvable special cases. The robust flow-over-time is already hard on series-parallel graphs and in general cannot be solved by a temporally repeated flow.

David Adjiashvili, ETH Zurich

Fault-tolerant shortest paths - Beyond the uniform failure model

The overwhelming majority of survivable (fault-tolerant) network design models assume a uniform scenario set. Such a scenario set assumes that every subset of the network resources (edges or vertices) of a given cardinality k comprises a scenario. While this approach yields problems with clean combinatorial structure and good algorithms, it often fails to capture the true nature of robustness coming from applica-

One natural refinement of the uniform model is obtained by partitioning the set of resources into faulty and secure resources. The scenario set contains every subset of at most k faulty resources. This work studies the Fault-Tolerant Path (FTP) problem, the counterpart of the Shortest Path problem in this failure model. We present complexity results alongside exact and approximation algorithms for FTP. We emphasize the vast increase in the complexity of the problem with respect to its uniform analogue, the Edge-Disjoint Paths problem.

Ebrahim Nasrabadi, Massachusetts Institute of Technology (with Dimitris Bertsimas, James Orlin)

On the power of randomization in robust optimization

Robust optimization can be viewed as a game involving two players, a decision maker and an adversary (or nature), who stand opposite each other. When only the cost parameters are subject to uncertainty, the decision maker chooses a solution (or a pure strategy) and the adversary selects adaptively a response after observing the decision maker's choice. We introduce a new modeling approach that allows the decision maker to select a random strategy. In this setting, the decision maker assigns a probability to each pure strategy and randomly selects a pure strategy according to the probabilities, where the adversary's response is based only on knowing the probability distribution and not its realization.

We show that the ratio between the value of the optimal pure strategy and the value of the optimal random strategy is bounded by the maximum number of affinely independent points in the feasible region. This bound is tight for several combinatorial optimization problems. We also show that an optimal random strategy can be computed in polynomial-time whenever the nominal problem (where costs are known) is solvable in polynomial time.

Sparse optimization & compressed sensing

Mon.3.H 1028

Global rate guarantees in sparse optimization

Organizer/Chair Michel Baes, ETH Zurich · Invited Session

Wotao Yin, Rice University (with Ming-Jun Lai)

Augmented L1 and nuclear-norm minimization with a globally linearly convergent algorithm

L1 minimization tends to give sparse solutions while the least squares (LS) give dense solutions. We show that minimizing the weighted sum of L1 and LS, with an appropriately small weight for the LS term, can efficiently recover sparse vectors with provable recovery guarantees. For compressive sensing, exact and stable recovery guarantees can be given in terms of the null-space property, restricted isometry property, spherical section property, and "RIPless" property of the sensing matrix. Moreover, the Lagrange dual problem of L1+LS minimization is convex, unconstrained, and differentiable; hence, a rich set of classical techniques such as gradient descent, line search, Barzilai-Borwein steps, quasi-Newton methods, and Nesterov's acceleration can be directly applied. We show that the gradient descent iteration is globally linearly convergent, and we give an explicit rate. This is the first global linear convergence result among the gradient-based algorithms for sparse optimization. We also present an algorithm based on the limited-memory BFGS and demonstrate its superior performance than several existing L1 solvers.

Lin Xiao, Microsoft Research (with Tong Zhang)

A proximal-gradient homotopy method for the sparse least-squares problem

We consider the ℓ_1 -regularized least-squares problem in the context of sparse recovery or compressed sensing. The standard proximal gradient method (iterative soft-thresholding) has low computational cost per iteration but a rather slow convergence rate. Nevertheless, when the solution is sparse, it often exhibits fast linear convergence in the end. We exploit this local linear convergence using a homotopy continuation strategy, i.e., we minimize the objective for a sequence of decreasing values of the regularization parameter, and use an approximate solution at the end of each stage to warm-start the next stage. Similar strategies have been studied in the literature, but there has been no theoretical analysis of their global iteration complexity. We show that under suitable assumptions for sparse recovery, the proposed homotopy strategy ensures that all iterates along the homotopy solution path are sparse. Therefore the objective function is effectively strongly convex along the path, and geometric convergence at each stage can be established. As a result, the overall iteration complexity of our method is $O(\log(1/\epsilon))$ for finding an ϵ -optimal solution.

Michel Baes, ETH Zurich (with Michael Buegisser, Arkadi Nemirovski)

First-order methods for eigenvalue optimization

Many semidefinite programming problems encountered in practice can be recast as minimizing the maximal eigenvalue of a convex combination of symmetric matrices. In this talk, we describe and analyze a

series of first-order methods for solving this problem when the input matrices are large (of dimension 1000 to 10000 and more) and mildly sparse. We propose several accelerating strategies, notably in the step-size selection, and based on randomization, and illustrate the theoretical and practical efficiency of the new approach.

Stochastic optimization

Mon.3.MA 141

Solution methods for constrained stochastic optimization

Organizer/Chair Sumit Kunnumkal, Indian School of Business · Invited Session

Lijian Chen, University of Louisville

Solving chance-constrained optimization by Bernstein polynomial approximation

We establish a Bernstein polynomial-based approximation scheme for a type of chance-constrained optimization in which the chance constraint is imposed on affine inequalities with a log-concave (log-concave, in short) continuous random vector in the right-hand side. To facilitate its implementation in practice, we only assume the log-concave and continuous joint distribution for the random vector without the closed-form distributional expression. We propose a new polynomial approximation scheme with Monte Carlo simulation to obtain the functional value and the gradient of the chance constraint as algorithmic inputs for optimization methods. The proposed scheme leads to a polynomial algorithm with considerable stability. We also address two other important issues. First, the approximation error can be well-controlled at only a reasonably low degree of the polynomial by employing the Chebyshev nodes. Second, through the epigraph convergence analysis, we show that the obtained optimal solution is converging to the original. Numerical results for known problem instances are presented.

Sumit Kunnumkal, Indian School of Business

Randomization approaches for network RM with choice behavior

We present new approximation methods for the network RM problem with customer choice. We have a fairly general model of customer choice behavior; we assume that customers are endowed with an ordered list of preferences among the products and choose the most preferred alternative among the available ones. The starting point for our methods is a dynamic program that allows randomization. An attractive feature of this dynamic program is that the size of its action space is linear in the number of itineraries. We present two approximation methods that build on this dynamic program and use ideas from the independent demands setting.

Gabor Rudolf, Sabanci University (with Nilay Noyan)

Optimization with multivariate conditional-value-at-risk constraints

For decision making problems under uncertainty it is crucial to specify the decision makers' risk preferences based on multiple stochastic performance measures. Incorporating multivariate preference rules into optimization models is a recent research area. Existing studies focus on extending univariate stochastic dominance rules to the multivariate case. However, enforcing such dominance constraints can be overly conservative in practice. As an alternative, we focus on the risk measure conditional value-at-risk (CVaR), introduce a multivariate CVaR relation, and propose an optimization model with multivariate CVaR constraints based on polyhedral scalarization. For finite probability spaces we develop a cut generation algorithm, where each cut is obtained by solving a mixed integer problem. We show that a multivariate CVaR constraint reduces to finitely many univariate CVaR constraints, which proves the finite convergence of our algorithm. We also show that our results can be extended to the wider class of coherent risk measures. The proposed approach provides a novel, flexible, and computationally tractable way of modeling preferences in stochastic multicriteria decision making.

Stochastic optimization

Mon.3.MA 144

Approximation algorithms for stochastic revenue management optimization

Organizer/Chair Retsef Levi, MIT Sloan School of Management · Invited Session

Retsef Levi, MIT Sloan School of Management (with Vineet Goyal, Danny Segev)

Near-optimal algorithms for assortment planning under dynamic substitution and stochastic demand

We consider a single-period assortment planning problem under a dynamic-substitution model with stochastic demand and give a polynomial time approximation scheme for the problem under fairly general assumptions. Our algorithm computes an assortment containing only a

small number of product types and obtains near-optimal revenue. We also present several complexity results for the problem that indicate that our assumptions are almost 'necessary' to solve it efficiently.

Dragos Ciocan, Massachusetts Institute of Technology (with Vivek Farias)

Dynamic allocation problems with volatile demand

We present a simple, easy to interpret algorithm for a large class of dynamic allocation problems with unknown, volatile demand. Potential applications include Ad Display problems and network revenue management problems. The algorithm operates in an online fashion and relies on re-optimization and forecast updates. The algorithm is robust (as witnessed by uniform worst case guarantees for arbitrarily volatile demand) and in the event that demand volatility (or equivalently deviations in realized demand from forecasts) is not large, the method is simultaneously optimal. Computational experiments, including experiments with data from real world problem instances, demonstrate the practicality and value of the approach. From a theoretical perspective, we introduce a new device – a balancing property – that allows us to understand the impact of changing bases in our scheme.

Cong Shi, Massachusetts Institute of Technology (with Retsef Levi)

Revenue management of reusable resources with advanced reservations

This paper studies a class of revenue management problems in systems with reusable resources and advanced reservations. A simple control policy called the class selection policy (CSP) is proposed based on solving a knapsack-type linear program (LP). It is shown that the CSP and its variants perform provably near-optimal under several classical asymptotic parameter regimes, such as the critically loaded and the Halfin-Whitt heavy-traffic regimes. The analysis is based on entirely new approaches that model the problem as loss network systems with advanced reservations. In particular, asymptotic upper bounds on the blocking probabilities are derived under the above mentioned heavy-traffic regimes. There have been very few results on loss network systems with advanced reservations, and we believe that the approaches developed in this paper will be applicable in other operations management and other applications domains.

Stochastic optimization

Mon.3.MA 376

Advances in probabilistically constrained optimization

Organizer/Chair Miguel Lejeune, George Washington University · Invited Session

Miguel Lejeune, George Washington University (with Alexander Kogan)

Threshold boolean form for the reformulation of joint probabilistic constraints with random technology matrix

We construct a partially defined boolean function (pdBf) representing the satisfiability of a joint probabilistic constraint with random technology matrix. We extend the pdBf as a threshold Boolean tight minorant to derive a series of integer reformulations equivalent to the stochastic problem. Computational experiments will be presented.

Ahmed Shabbir, Georgia Institute of Technology (with Dimitri Papageorgiou)

Probabilistic set covering with correlations

We formulate deterministic mixed-integer programming models for distributionally robust probabilistic set covering problems with correlated uncertainties. By exploiting the supermodularity of certain substructures we develop strong valid inequalities to strengthen the formulations. Computational results illustrate that our modeling approach can outperform formulations in which correlations are ignored and that our algorithms can significantly reduce overall computation time.

Pavlo Krokhmal, University of Iowa (with Alexander Vinel)

On polyhedral approximations in p -order conic programming

We consider (generally mixed integer) p -order conic programming problems that are related to a class of stochastic optimization models with risk-based objectives or constraints. A recently proposed approach to solving problems with p -cone constraints relies on construction of polyhedral approximations of p -cones. In this talk we discuss computational techniques for efficient solving of the corresponding approximating problems. The conducted case studies on problems of portfolio optimization and data mining demonstrate that the developed approach compare favorably against a number of benchmark methods.

Telecommunications & networks

Mon.3.H 3002

Optimization of optical networks

Organizer/Chair Brigitte Jaumard, Concordia University · Invited Session

Brigitte Jaumard, Concordia University (with Minh Bui, Anh Hoang)

Path vs. cutset column generator models for the design of IP-over-WDM optical networks

Multi-layer optical networks have recently evolved towards IP-over-WDM networks. Therein, in order to avoid protection/restoration redundancies against either single or multiple failures, synergies need to be developed between IP and optical layers in order to reduce the costs and the energy consumption of the future IP-over-WDM networks.

We propose two new column generation models. The first one is an enhanced cutset model. The second one is a path model, based on a multi-flow formulation. Both models can solve exactly most benchmark instances, which were only solved heuristically so far.

Jørgen Haahr, University of Copenhagen (with Thomas Stidsen, Martin Zachariassen)

Heuristic planning of shared backup path protection

Protecting communication networks against failures is becoming increasingly important as they have become an integrated part of our society. Cable failures are fairly common, but it is unacceptable for a single cable failure to disconnect communication even for a very short period and hence protection schemes are employed. The most utilized protection schemes today are ring protection and 1+1 protection. Both schemes do however require a significant extra network capacity. A more advanced protection method such as shared backup path protection (SBPP) can be used instead. SBPP is a simple but efficient protection scheme that can be implemented in backbone networks with technology available today. We prove that SBPP planning is a NP-hard optimization problem. Previous work confirms that it is time-consuming to solve the problem in practice using exact methods. We present heuristic algorithms and lower bound methods for the SBPP planning problem. Experimental results show that the heuristic algorithms are able to find good quality solutions in few minutes. A solution gap of less than 12% was achieved for seven test networks.

Philippe Mahey, ISIMA - Université de Clermont-Ferrand (with Christophe Duhamel, Alexandre Martins, Rodney Saldanha, Mauricio Souza)

Algorithms for lower and upper bounds for routing and wavelength assignment

In all-optical networks a traffic demand is carried from source to destination through a lightpath, which is a sequence of fiber links carrying the traffic from end-to-end. The wavelength continuity constraint implies that to a given lightpath a single wavelength must be assigned. Moreover, a particular wavelength cannot be assigned to two different lightpaths sharing a common physical link. The routing and wavelength assignment (RWA) problem arises in this context as to establish lightpaths to carry traffic demands. The problem is found in two versions: (i) to minimize the number of wavelengths to meet fixed traffic requests; and (ii) to maximize the traffic requests satisfied given a fixed number of wavelengths. In this work, we develop algorithms to tackle the RWA via lower and upper bounds. We present, by combining column generation models from the literature, a fast procedure to obtain lower bounds. We also present heuristic approaches based on variable neighborhood descent (VND) with iterated local search (ILS) for the min-RWA. We report numerical results showing optimality gaps obtained on benchmark instances from the literature.

Variational analysis

Mon.3.H 2035

Lower order exact penalty functions

Organizer/Chair Xiaoqi Yang, The Hong Kong Polytechnic University · Invited Session

Xiaoqi Yang, The Hong Kong Polytechnic University (with Kaiwen Meng)

Optimality conditions via exact penalty functions

In this presentation, we study KKT optimality conditions for constrained nonlinear programming problems and strong and Morukhovich stationarities for mathematical programs with complementarity constraints using l_p penalty functions with $0 \leq p \leq 1$. We introduce some optimality indication sets by using contingent derivatives of penalty function terms. Some characterizations of optimality indication sets by virtue of the original problem data are obtained. We show that KKT optimality condition holds at a feasible point if this point is a local minimizer of some l_p penalty function with p belonging to the opti-

mality indication set. Our result on constrained nonlinear programming includes some existing ones in the literature as special cases.

Boshi Tian, The Hong Kong Polytechnic University (with Xiaoqi Yang)

An interior-point $\ell_{1/2}$ -penalty method for nonlinear programming

In this presentation, we solve general nonlinear programming problems by using a quadratic relaxation scheme for their $\ell_{1/2}$ -lower order penalty problems. Combining an interior point method, we propose an interior point $\ell_{1/2}$ -penalty function method, and design some robust algorithms. Using some relaxed constraint qualifications, we obtain first-order optimality conditions of relaxed $\ell_{1/2}$ -lower order penalty problems. We also carry out numerical experiments for three test problem sets, which contain small scale and medium scale test problems, large scale test problems and optimization problems with different kinds of degenerate constraints, respectively. The comparison of the numerical performance of our method with other existing interior point penalty methods shows that our method in general performs better in terms of CPU time, iteration number, barrier parameter, and penalty parameter.

Zhangyou Chen, The Hong Kong Polytechnic University (with Xiaoqi Yang, Jinchuan Zhou)

Exact penalty functions for semi-infinite programming

We study optimality conditions of an inequality constraint semi-infinite optimization problem from the point of view of exact penalty functions. We introduce two types of penalty functions for the semi-infinite optimization problem, L_∞ -type and integral-type penalty functions, and investigate their exactness relations as well as their relations with corresponding calmness properties, respectively. We establish first-order optimality conditions for the semi-infinite optimization problem via (esp. lower order) exact penalty functions. Finally, we apply our results to a generalized semi-infinite optimization problem by virtue of a double penalization technique.

Variational analysis

Mon.3.H 2051

Some applications of variational analysis

Organizer/Chair Nguyen Dong Yen, Institute of Mathematics, Vietnam Academy of Science and Technology · Invited Session

Mau Nam Nguyen, University of Texas-Pan American

Variational analysis of minimal time functions with unbounded dynamics and generalized smallest enclosing circle problems

The smallest enclosing circle problem introduced in the 19th century by J. J. Sylvester asks for the circle of smallest radius enclosing a given set of finite points in the plane. In this talk we will present new results on variational analysis of minimal time functions generated by unbounded constant dynamics and discuss their applications to generalized versions of the smallest enclosing circle problem. This approach continues our effort in applying variational analysis to the well-established field of facility location.

Andrew Eberhard, RMIT University (with Boris Mordukhovich, Charles Pearce, Robert Wenczel)

Approaches to optimality conditions using nonsmooth and variational methods

In this talk we survey a number of approaches to the development of optimality conditions that delay the introduction of regularity conditions. In doing so they generalize the standard Lagrangian optimality conditions and second order sufficiency conditions in various ways. The infimal regularization and a mixture of subhessian and coderivative like techniques are used in combination with variational methods.

Gue Myung Lee, Pukyong National University (with Chieu Nguyen Huy)

On constraint qualifications for mathematical programs with equilibrium constraints

Mathematical program with equilibrium constraints (shortly, MPEC) has been the subject of intensive research during the last decades. We introduce a relaxed version of a constraint qualification for the MPEC formulated as optimization problems with complementarity constraints. We present that the relaxed version is an MPEC-constraint qualification for M-stationarity. Using the limiting second-order subdifferential for $C^{1,1}$ functions, we show that the relaxed version is strong enough to ensure the validity of a local MPEC-error bound under a certain additional assumption.

Approximation & online algorithms

Tue.1.H 3010

Approximation in algorithmic game theory

Organizer/Chair Chaitanya Swamy, University of Waterloo · Invited Session

Konstantinos Georgioui, University of Waterloo (with Chaitanya Swamy)

Black-box reductions for cost-sharing mechanism design

We consider the design of *strategyproof* cost-sharing mechanisms, focusing mainly on the single-dimensional setting. We give two simple, but extremely versatile, *black-box reductions*, that in combination reduce the cost-sharing mechanism-design problem to the *algorithmic* problem of finding a minimum-cost solution for a set of players. Our first reduction shows that any α -approximation, truthful mechanism for the social-cost-minimization (SCM) problem that satisfies a technical no-bossiness condition can be morphed into a truthful mechanism that achieves an $\alpha \log n$ -approximation where the prices recover the cost incurred. This disconnects the task of truthfully computing an outcome with near-optimal social cost from the cost-sharing problem. Complementing this, our second reduction shows that any LP-based ρ -approximation for the problem of finding a min-cost solution for a set of players can be used to obtain a truthful, no-bossy, $(\rho+1)$ -approximation for the SCM problem (and hence, a truthful $(\rho+1) \log n$ -approximation cost-sharing mechanism).

Berthold Vöcking, RWTH Aachen University

A universally-truthful approximation scheme for multi-unit auctions

We present a randomized, polynomial-time approximation scheme for multi-unit auctions. Our mechanism is truthful in the universal sense, i.e., a distribution over deterministically truthful mechanisms. Previously known approximation schemes were truthful in expectation which is a weaker notion of truthfulness assuming risk neutral bidders. The existence of a universally truthful approximation scheme was questioned by previous work showing that multi-unit auctions with certain technical restrictions on their output do not admit a polynomial-time, universally truthful mechanism with approximation factor better than two.

Our new mechanism employs VCG payments in a non-standard way: The deterministic mechanisms underlying our universally truthful approximation scheme are not maximal in range and do not belong to the class of affine maximizers which, on a first view, seems to contradict previous characterizations of VCG-based mechanisms. Instead, each of these deterministic mechanisms is composed of a collection of affine maximizers, one for each bidder which yields a subjective variant of VCG.

Deeparnab Chakrabarty, Microsoft Research, India (with Anand Bhalgat, Sanjeev Khanna, Chaitanya Swamy)

Matching markets with ordinal preferences

In this talk we will consider the following basic economic problem: given n agents and n items with agents having a preference over these items, how should we allocate items to agents? The answer will depend on what we hope to achieve – we will see this goal is not very clear always. Furthermore, we would like our mechanisms which achieve these goals to be *strategyproof* – we will see that the definition of the same also is also arguable. After covering some groundwork, we'll describe some new analysis of old mechanisms, and (also new) analysis of some new algorithms.

Combinatorial optimization

Tue.1.H 3004

Generalizing shortest paths, cycles, and Steiner trees

Chair Stefano Gualandi, University of Pavia

Stefano Gualandi, University of Pavia (with Federico Malucelli)

Resource constrained shortest paths with a super additive objective function

We present an exact solution approach to the constrained shortest path problem with a super additive objective function. This problem generalizes the constrained shortest path problem by considering a cost function $c(\cdot)$ such that, given two consecutive paths P_1 and P_2 , the following relation holds $c(P_1 \cup P_2) \geq c(P_1) + c(P_2)$. Since super additivity invalidates the Bellman optimality conditions, known resource constrained shortest path algorithms must be revisited. Our exact solution algorithm is based on a two stage approach: first, the size of the input graph is reduced as much as possible using a Lagrangian reduced-cost fixing algorithm. Then, since the Lagrangian relaxation provides a tight lower bound, the optimal solution is computed using a near-shortest path enumerative algorithm that exploits such lower bound. We present two alternative algorithms to solve the Lagrangian relaxation, and compare their behaviors in terms of reduction of the input graph, quality of the lower bounds, and computation time. Computational results show

that the constrained shortest path with a super additive objective function is indeed a challenging problem.

Hiroshige Dan, Kansai University (with Tatsuya Shigetou)

Finding the shortest cycle in directed graphs under some constraints on passing vertices and paths

In this research, we propose a problem to find the shortest cycle in directed graphs under some constraints on passing vertices and paths. The proposed problem is as follows: The origin and designated vertices are given. We want to find the shortest cycle which starts from the origin and passes all the designated vertices. Also, the cycle has a state which depends on the path from the origin and the transition along the cycle changes it. Each vertex has acceptable states, and the path can reach a vertex when the current state is acceptable for it. This kind of problem occurs from the maintenance of large machinery. For example, when an elevator is under maintenance, a worker has to do the predetermined operations. Also, he/she has to do some operations for ensuring his/her safety during the maintenance. However, he/she can skip some operations as long as the safety is ensured. Moreover, a state of an elevator is transiting by operations. We can deal with such situations by our proposed problem. For this problem, we propose a method which is based on a method for the asymmetric traveling salesman problem. We will show computational results in our presentation.

Marika Karbstein, Zuse Institute Berlin

Approximation and min-max results for the Steiner connectivity problem

The Steiner connectivity problem is to connect a set of terminal nodes in a graph by a cost minimal set of paths; it generalizes the Steiner tree problem to hypergraphs. The problem is known to be approximable within a factor of $\log k$ if all nodes are terminals. We discuss its approximability if all paths contain at most k edges and provide, in particular, a $k+1$ approximation if all paths contain at most k terminals. The two terminal case gives rise to a TDI description; this yields a combinatorial companion theorem to Menger's theorem for hypergraphs and characterizes paths and cuts in hypergraphs as a blocking pair.

Combinatorial optimization

Tue.1.H 3005

Submodularity and covering

Organizer/Chair Jon Lee, University of Michigan · Invited Session

Maxim Sviridenko, University of Warwick (with Rishi Saket)

New and improved bounds for the minimum set cover problem

We study the relationship between the approximation factor for the set-cover problem and the parameters D , the maximum cardinality of any subset, and k , the maximum number of subsets containing any element of the ground set. We show an LP rounding based approximation of $(k-1)(1 - e^{-\ln D/(k-1)}) + 1$, which is substantially better than the classical algorithms when k is approximately $\ln D$, and also improves on related previous works. For the interesting case when $k = \theta(\log D)$ we also exhibit an integrality gap which essentially matches our approximation algorithm.

We also prove a hardness of approximation factor of $\Omega(\log D/(\log \log D)^2)$ when $k = \theta(\log D)$. This is the first study of the hardness factor specifically for this range of k and D , and improves on the only other such result implicitly proved before.

Andreas Krause, ETH Zurich (with Daniel Golovin)

Adaptive submodularity: Theory and applications in active learning and stochastic optimization

Solving stochastic optimization problems under partial observability, where one needs to adaptively make decisions with uncertain outcomes, is a fundamental but notoriously difficult challenge. In this talk, I will introduce a new concept called adaptive submodularity, which generalizes submodular set functions to adaptive policies.

In many respects adaptive submodularity plays the same role for adaptive problems as submodularity plays for nonadaptive problems. Specifically, just as many nonadaptive problems with submodular objectives have efficient algorithms with good approximation guarantees, so too do adaptive problems with adaptive submodular objectives. We use this fact to recover and generalize several previous results in adaptive optimization, including results for active learning and adaptive variants of maximum coverage and set cover. We show how to apply these results to several applications, including observation selection and sensor placement problems, sequential experimental design, and adaptive viral marketing.

Rico Zenklusen, MIT (with Michel Goemans, Neil Olver, Thomas Rothvoss)

Matroids and integrality gaps for hypergraphic Steiner tree relaxations

Until recently, LP relaxations have only played a very limited role in

the design of approximation algorithms for the Steiner tree problem. In particular, no (efficiently solvable) Steiner tree relaxation was known to have an integrality gap bounded away from 2. This changed when Byrka, Grandoni, Rothvoss and Sanità demonstrated in 2010 a $\ln(4) + \epsilon \approx 1.39$ approximation algorithm based on a so-called hypergraphic LP relaxation. Interestingly, even though their approach is LP based, they do not obtain a matching bound on the integrality gap, showing only a weaker 1.55 bound by other methods.

We show that indeed the integrality gap is bounded by $\ln(4)$. In the process, we obtain a much better structural understanding of hypergraphic LPs, as well as more efficient algorithms. Our approach is heavily based on techniques from the theory of matroids and submodular functions.

Combinatorial optimization

Tue.1.H 3008

LP based approximation algorithms for location and routing

Organizer/Chair Viswanath Nagarajan, IBM Research · Invited Session

Jarosław Byrka, University of Wrocław (with Aravind Srinivasan, Chaitanya Swamy)

Fault-tolerant facility location: A randomized dependent LP-rounding algorithm

We give a new randomized LP-rounding 1.725-approximation algorithm for the metric Fault-Tolerant Uncapacitated Facility Location problem. This improves on the previously best known 2.076-approximation algorithm of Swamy & Shmoys. To the best of our knowledge, our work provides the first application of a dependent-rounding technique in the domain of facility location. The analysis of our algorithm benefits from, and extends, methods developed for Uncapacitated Facility Location; it also helps uncover new properties of the dependent-rounding approach. An important concept that we develop is a novel, hierarchical clustering scheme. Typically, LP-rounding approximation algorithms for facility location problems are based on partitioning facilities into disjoint clusters and opening at least one facility in each cluster. We extend this approach and construct a laminar family of clusters, which then guides the rounding procedure: this allows us to exploit properties of dependent rounding, and provides a quite tight analysis resulting in the improved approximation ratio.

Anna Blasiak, Cornell University (with Aaron Archer)

Improved approximation algorithms for the minimum latency problem via prize-collecting paths

The minimum latency problem (MLP) is a well-studied variant of the traveling salesman problem. In it, the server's goal is to minimize average latency of clients prior to being served, rather than total latency of the server. Unlike most combinatorial optimization problems, the MLP is NP-hard even on trees (Sitters 2001). Furthermore, all MLP approximation algorithms known for general metrics are based on trees, and the best ratio known for both cases was 3.59, prior to our work.

We give a 3.03-approximation algorithm for trees, the first improvement since 1996. Our 3.03-approximation algorithm works for any class of graphs in which the related prize-collecting path problem is solvable in polynomial time, like graphs of constant treewidth. More generally, for any class of graphs that admit a Lagrangian-preserving β -approximation algorithm for the prize-collecting path problem, we can use our algorithm as a black box to achieve a 3.03β -approximation for the MLP. Our analysis uses a solution of an infinite-dimensional linear program to analyze a finite-dimensional factor-revealing linear program.

Zachary Friggstad, University of Waterloo (with Mohammad R. Salavatipour, Zoya Svitkina)

A logarithmic approximation for the directed latency problem

In the directed latency problem, we are given an asymmetric metric and a start node s . The goal is to find a Hamiltonian path starting at s that minimizes the average distance of the nodes from the start of the path. An $O(\log n)$ approximation for this problem will be presented whose analysis also bounds the integrality gap of an LP relaxation by the same factor. This improves on the previous best approximation of $O(n^{1/2+\epsilon})$ by Nagarajan and Ravi. Our approach requires bounds on integrality gaps of LP relaxations for the asymmetric traveling salesman path problem and a variant using two paths.

Combinatorial optimization

Tue.1.H 3012

Scheduling III

Chair Sandro Bosio, ETH Zürich

Evgeny Gafarov, École Nationale Supérieure des Mines Saint Étienne (with Alexandre Dolgui, Alexander Lazarev)

Two-station single track railway scheduling problem with equal speed of trains

The single track railway scheduling problem with two stations and Q segments of the track is considered. Two subsets of trains N_1' and N_2' are given, where trains from N_1' go from the station 1 to the station 2, and trains from N_2' go in the opposite direction. The speed of trains over each segment is the same. A polynomial time reduction from the problem under consideration to a special case of the single machine equal-processing-time scheduling problem with setup times is presented. For this special case with different objective function under different constraints, polynomial time solution algorithms are presented.

Jens Poppenborg, Clausthal University of Technology (with Stigrid Knust)

Modeling the resource-constrained project scheduling problem with resource transfers using a graph approach.

This presentation deals with the resource-constrained project scheduling problem (RCPSP) with resource transfers. Here, resource transfers are classified into two different categories: first- as well as second-tier resource transfers. While first-tier resource transfers include all resource transfers where resources are directly transferred from one activity to the next, second-tier resource transfers include all resource transfers where a resource is used to transport another resource between two successive activities, i.e. this other resource can not be transferred on its own.

The problem described here is modeled using a graph approach. For this, the activities are modeled as nodes while the resource transfers or resource flows between these activities are modeled as arcs such that an arc between two nodes corresponds to the transfer of a certain amount of units of a resource from one activity to another. Additionally, each arc is associated with the required transfer time such that schedules can be generated using longest path calculations. For this model, different neighborhood structures are introduced and some results are presented.

Sandro Bosio, ETH Zürich (with David Adjashvili, Kevin Zimmer)

Mailroom production planning

In a multi-feeder mailroom machine, folders (e.g., newspapers) run at high-speed through a line of independent feeders, receiving by each active feeder an advertising insert. A job is a subset of inserts to be bundled in a given number of copies, which requires a certain production time. Scheduling a job batch involves deciding the job order and, for each job, the assignment of the job inserts to the feeders.

Loading an insert on a feeder requires a given setup time, and can only be done while the feeder is idle. Given a schedule, violated setup requirements have to be resolved by stopping the machine, completing the loads, and restarting the machine. As the time needed to restart the machine dominates the setup time, minimizing the makespan is equivalent to minimizing the machine stops. Alternative objective functions are the minimization of the inserts loads (number of times each insert is loaded) and the minimization of the inserts splits (number of different feeders on which each insert is loaded). We study the complexity of the problem for each objective function, for both fixed and variable job sequence. We also consider lexicographic bi-objective optimization variants.

Combinatorial optimization

Tue.1.H 3013

Trees and words

Chair Winfried Hochstättler, FernUniversität in Hagen

Winfried Hochstättler, FernUniversität in Hagen (with Stephan Andres)

Some heuristics for the binary paint shop problem and their expected number of colour changes

In the binary paint shop problem we are given a word on n characters of length $2n$ where every character occurs exactly twice. The objective is to color the letters of the word in two colors, such that each character receives both colors and the number of color changes of consecutive letters is minimized. Amini et. al proved that the expected number of color changes of the heuristic greedy coloring is at most $2n/3$. They also conjectured that the true value is $n/2$. We verify their conjecture and, furthermore, compute an expected number of $2n/3$ colour changes for a heuristic, named *red first*, which behaves well on some worst case examples for the greedy algorithm. From our proof method,

finally, we derive a new recursive greedy heuristic which achieves an average number of $2n/5$ color changes.

Marcin Krzywkowski, Gdańsk University of Technology

An algorithm listing all minimal dominating sets of a tree

We provide an algorithm listing all minimal dominating sets of a tree of order n in time $\mathcal{O}(1.4656^n)$. This leads to that every tree has at most 1.4656^n minimal dominating sets. We also give an infinite family of trees of odd and even order for which the number of minimal dominating sets exceeds 1.4167^n , thus exceeding $2^{n/2}$. This establishes a lower bound on the running time of an algorithm listing all minimal dominating sets of a given tree.

Yasuko Matsui, Tokai University (with Kento Kizaka, Hiroki Yoshida)

An enumeration algorithm for the optimal cost vertex-colorings for trees

The cost vertex-coloring problem is to find a vertex-coloring of a graph such that the total costs of vertices is as small as possible. In 1997, Kroon et al. gave the problem can be solved in linear time for trees. In this talk, we first propose an enumeration algorithm for the optimal cost vertex-colorings for trees, if there exists. Our algorithm has a polynomial-time delay property and requires polynomial space.

Combinatorial optimization

Tue.1.H 3021

Data structures and algorithms for VLSI routing

Organizer/Chair Tim Nieberg, University of Bonn · Invited Session

Dirk Müller, University of Bonn

Multi-flows and generalizations in VLSI routing

In the (global) routing of VLSI chips, limited space must be shared by different connections, so-called nets. In this context, multi-commodity flow problems arise naturally, and approximation schemes have been applied to them and their generalizations to fractional Steiner tree packing successfully for more than 15 years, the traditional objective being wire length minimization.

Technology scaling causes a growing need to extend global routing to directly consider other objectives and additional constraints, such as signal delays, power consumption and manufacturing yield. All these depend non-linearly on the spacing between wires. Because these dependencies are given by convex functions, we can show that a fractional relaxation of the extended global routing problem can be formulated as a block-angular min-max resource sharing problem. We present a simple approximation scheme for this problem which generalizes and improves various previous results, and can be parallelized very efficiently. Further, we show experimental results on recent industrial chips with millions of nets and resources.

Christian Schulte, University of Bonn (with Michael Gester, Dirk Müller, Tim Nieberg, Christian Panten, Jens Vygen)

Efficient algorithms and data structures in VLSI detailed routing

We present the core elements of detailed routing in BonnRoute. Long-distance connections are computed by a fast, interval based path search algorithm using efficient data structures for routing space representation. With advanced pin access strategies we avoid local conflicts in dense pin configurations. BonnRoute is able to handle complex design rules in modern technologies, and is used in practice on current, real world designs. Compared to an industrial routing tool it is much faster and gives better results in terms of total connection length and number of detours.

Michael Gester, University of Bonn (with Dirk Müller, Tim Nieberg, Christian Panten, Christian Schulte, Jens Vygen)

New challenges in chip design driven by technology scaling

While structures on modern computer chips are getting smaller and smaller, e.g., by the use of more sophisticated lithography techniques, the design rules which chip design software has to respect are increasing in number and are getting more and more complex. This leads to various new algorithmical challenges in chip design. We discuss some of the most important challenges from a practical and from a theoretical perspective. Special emphasis is put on double patterning lithography. Here all structures on a single chip layer are assigned to two different production steps in manufacturing. This assignment can be considered as a coloring problem on a conflict graph which arises in different areas of chip design and has fundamental consequences for the whole design flow of modern computer chips.

Complementarity & variational inequalities

Tue.1.MA 041

Complementarity properties of linear transformations on Euclidean Jordan algebras

Organizer/Chair Jiyuan Tao, Loyola University Maryland · Invited Session

Jeyaraman Irulappasamy, The Institute of Mathematical Sciences

P and semimonotonicity properties of linear transformations on Euclidean Jordan algebras

Let $(V, \circ, \langle \cdot, \cdot \rangle)$ be a Euclidean Jordan algebra with the symmetric cone $K = \{x \circ x : x \in V\}$. Given a linear transformation $L : V \rightarrow V$ and $q \in V$, the *linear complementarity problem* over the symmetric cone, $\text{LCP}(L, q)$, is to find a vector $x \in V$ such that $x \in K$, $y := L(x) + q \in K$, and $\langle x, y \rangle = 0$. This problem includes the standard, semidefinite and second order linear complementarity problems. To study the existence and uniqueness of solution of the standard linear complementarity problem, several matrix classes have been introduced which includes P and semimonotone matrices. Motivated by these concepts, the matrix classes were extended to linear transformations on S^n , the space of all $n \times n$ real symmetric matrices, and further extended to Euclidean Jordan algebras. In this talk, we introduce various P and semimonotonicity properties and describe some interconnections between them. We also discuss how these concepts are significant in the study of $\text{LCP}(L, q)$.

Jiyuan Tao, Loyola University Maryland

The completely-Q property for linear transformations on Euclidean Jordan algebras

In this talk, we present a characterization of the completely-Q property for linear transformations on Euclidean Jordan algebras and show the completely-Q property and related properties on Euclidean Jordan algebras.

Roman Sznajder, Bowie State University (with M. Seetharama Gowda, Jiyuan Tao)

Complementarity properties of linear transformations on product spaces via Schur complements

In this paper we extend, in a natural way, the notion of the Schur complement of a subtransformation of a linear transformation defined on the product of two simple Euclidean Jordan algebras or, more generally, on two finite dimensional real Hilbert spaces. We study various complementarity properties of linear transformations in relations to subtransformations, principal pivot transformations, and Schur complements. We also investigate some relationships with dynamical systems.

Complementarity & variational inequalities

Tue.1.MA 313

Matrix classes for linear complementarity problems

Organizer/Chair Todd Munson, Argonne National Laboratory · Invited Session

Todd Munson, Argonne National Laboratory

Preprocessing with composite matrices

In this talk, I present a class of matrices called composite matrices that include nonnegative matrices with positive diagonals and P -matrices, and form a subset of the strictly semi-monotone matrices. These matrices have interesting properties that are useful when preprocessing linear complementarity problems to improve the model formulation. In particular, we can easily include implied bounds on the variables for subproblems identified by finding diagonal composite matrix blocks.

Richard Cottle, Stanford University (with Ilan Adler)

Lemke's algorithms and matrix classes for the linear complementarity problem

This survey paper deals with the algorithms of Carleton E. Lemke for the linear complementarity problem. Special attention is paid to the matrix classes for which these algorithms are known to be applicable. The algorithms were not designed to obtain more than one solution, although in some cases, repeated application of a variant of the algorithm will yield several solutions. Nevertheless, there are instances where some solutions are "elusive" or "inaccessible" by the algorithm in question. We review efforts that have been made to overcome this limitation. We also examine other equilibrium problems and investigate a different (possibly novel) algorithm for exposing "elusive" equilibrium points.

Gabriele Uchida, University of Vienna (with Immanuel Bomze, Werner Schachinger)

Think co(mpletely) positive! Algebraic properties of matrices belonging to the copositive or related cones

In the context of conic programming (optimizing a linear functional over a convex cone subject to linear constraints) properties of, and relations between, corresponding matrix classes play an important role. A well known subclass of this problem family is semi-definite programming and, to a quickly expanding extent, copositive programming.

Therefore the cones of copositive matrices and the dual cone, all completely positive matrices, are studied and structural algebraic properties provided. Several (counter-)examples demonstrate that many relations familiar from semidefinite optimization may fail in the copositive context, illustrating the transition from polynomial-time to NP-hard worst-case behaviour.

Conic programming

Tue.1.H 2036

Smoothing methods for symmetric cone complementarity problems

Chair Shunsuke Hayashi, Kyoto University

Cong Cheng, The Logistics Institute, Northeastern University, China (with Lixin Tang)

A smoothing method for symmetric cone complementarity problems

This paper considers the mathematical program with symmetric cone complementarity constraints (MPSCCC), which is a general form for the nonlinear complementarity problem (NLP), the semi-definite complementarity problem (SDCP), and the second-order complementarity problem (SOCP). The necessary optimality condition and the second order sufficient condition are proposed. By means of the smoothed Fischer-Burmeister function, the smoothing Newton method is employed to solve the problem. At last, a inverse problem which actually is a NLP, is solved as an example.

Ellen Fukuda, State University of Campinas (with Masao Fukushima, Paulo Silva)

Differentiable exact penalty functions for nonlinear second-order cone programs

We propose a method to solve nonlinear second-order cone programs (SOCPs), that uses a continuously differentiable exact penalty function as a base. The construction of the penalty function is given by incorporating a multipliers estimate in the augmented Lagrangian for SOCPs. Under the nondegeneracy assumption and the strong second-order sufficient condition, we show that a generalized Newton method has global and superlinear convergence. We also present some preliminary numerical experiments.

Shunsuke Hayashi, Kyoto University (with Masao Fukushima, Takayuki Okuno, Hiroshi Yamamura)

A smoothing SQP method for mathematical programs with second-order cone complementarity constraints

We focus on the mathematical program with second-order cone complementarity constraints, which contains the well-known mathematical program with nonnegative complementarity constraints as a subclass. For solving such a problem, we propose an algorithm based on the smoothing and the sequential quadratic programming (SQP) methods. We first replace the second-order cone complementarity constraints with equality constraints using the smoothing natural residual function, and apply the SQP method to the smoothed problem while decreasing the smoothing parameter. The SQP type method proposed in this paper has an advantage that the exact solution of each subproblem can be calculated easily since it is a convex quadratic programming problem. We further show that the proposed algorithm possesses the global convergence property under the Cartesian P_0 and some nonsingularity assumptions. We also observe the effectiveness of the algorithm by means of numerical experiments.

Conic programming

Tue.1.H 2038

New advances in conic programming

Organizer/Chair Cristian Dobre, University of Groningen · Invited Session

Julia Sponzel, Universität Trier

On standard quadratic optimization problems

Many NP-hard problems can be reformulated as copositive programs, i.e., linear optimization problems over the copositive cone. The difficulty then lies in the cone constraint. Testing copositivity of a given matrix Q is a co-NP-complete problem which can be stated as a standard quadratic optimization problem of the following form

$$\begin{aligned} \min \quad & x^T Q x \\ \text{s.t.} \quad & e^T x = 1 \\ & x \geq 0. \end{aligned} \quad (\text{StQP})$$

The matrix Q is copositive if and only if the optimal value of (StQP) is non-negative. We consider relaxations of this problem and the case where Q is a 5×5 -matrix which is of special interest, since there are copositive 5×5 -matrices which cannot be decomposed into the sum of a positive

semidefinite and a nonnegative matrix whereas this is possible for every copositive $n \times n$ -matrix with $n \leq 4$.

Cristian Dobre, University of Groningen (with Mirjam Duer, Frank Vallentin)
Infinite dimensional semidefinite programming

In this talk we investigate the infinite dimensional analogue of the primal and dual semidefinite matrix cones. Whereas in the finite case the cone of positive semidefinite matrices is self-dual this is no longer true in infinite dimensions. We introduce the suitable infinite dimensional objects, formulate the pair of primal-dual semidefinite programs and characterize the extremal rays of the dual infinite semidefinite cone. The technique we use employs the theory of reproducing kernels. Applying the same technique to the finite case gives a new proof and interesting new insights on the extremal semidefinite matrices.

Juan Vera, Tilburg University (with Cristian Dobre)

Exploiting symmetry in copositive programs

We study the solution of copositive programs using a sequence of improving relaxations, as the ones used by Gaddar-Vera-Anjos for polynomial programs. This method consists of using interactively a master-subproblem scheme; the master solves a conic-relaxation of the original problem, while the subproblem improves the cone used in the relaxation using dual information from the master.

We show how symmetry of the original copositive formulation can be used to reduce both the master and subproblem. To reduce the master, techniques to exploit symmetry in semidefinite programming – which are becoming standard nowadays – are used; reducing the subproblem requires exploiting the symmetry of Polya-like representations for copositive polynomials in a novel manner.

Constraint programming

Tue.1.H 3003A

Constraint programming for routing and scheduling

Organizer/Chair Louis-Martin Rousseau, CIRRELT – Polytechnique Montréal - Invited Session

Jean-Guillaume Fages, École des Mines de Nantes (with Xavier Lorca)

Solving the traveling salesman problem with constraint programming

The Traveling Salesman Problem (TSP) is one of the most studied problem by the operation research community and has various practical applications, such as vehicle routing problems of logistics, microchips production optimization or even scheduling. Recent improvements have enabled constraint programming (CP) approaches to tackle medium size TSP instances. We discuss basic CP representations of the TSP and provide a short survey over state of the art models as well as an experimental study.

Arnaud Malapert, I3S CNRS – Université Nice Sophia Antipolis (with Christelle Guéret, Louis-Martin Rousseau)

Scheduling a batch processing machine with constraints

We present a constraint programming approach for a batch processing machine on which a finite number of jobs of non-identical sizes must be scheduled. A parallel batch processing machine can process several jobs simultaneously and we aim to minimize several regular objective functions. The constraint programming formulation proposed relies on the decomposition of the problem into finding an assignment of the jobs to the batches, and then scheduling the batches on a single machine. This formulation is enhanced by a new optimization constraint which is based on relaxed problems and applies cost-based domain filtering techniques. Cost based domain filtering aims to remove combination of values which cannot lead to solutions whose cost is better than the best one found so far. Experimental results demonstrate the efficiency of cost-based domain filtering techniques. Comparisons to other exact approaches clearly show the benefits of the proposed approach.

Louis-Martin Rousseau, CIRRELT – Polytechnique Montréal (with Nicolas Chapados, Marc Joliveau, Pierre L'Écuyer)

Formal language for retail store workforce scheduling

The dual role played by the sale personnels in retail store industry, which can be seen as a costly resource, as well as a set of agents that generate incomes, makes this area very specific as, unlike traditional approaches whose goal is to minimize the operating costs, the schedules of the employees can be optimized such that it directly maximize the net incomes generated by the store over a given horizon (e.g., a day or a week). In this framework, we introduce a constraint program (CP) and a mixed integer program (MIP), both based on the use of a formal language, that schedule the workforce of a retail store while considering both operating costs and operating incomes. Comparison on more than 5000 day instances measured in a clothing and apparel chain will demonstrate the advantage of CP to accurately handle the specific work regulation rules of the retailer in comparison to MIP.

Derivative-free & simulation-based opt.

Tue.1.H 3503

Derivative-free optimization and constraints

Organizers/Chairs Stefan Wild, Argonne National Laboratory; Luis Nunes Vicente, University of Coimbra - Invited Session

Giovanni Fasano, University Ca' Foscari of Venice (with Giampaolo Liuzzi, Stefano Lucidi, Francesco Rinaldi)

An exact penalty method for constrained Lipschitz optimization

In this work we consider the minimization of a real function subject to inequality constraints along with bound constraints on the variables. In the latter problem we assume that both the objective function and the constraints are Lipschitz continuous. We first study the solution of a bound constrained minimization problem and propose a line search type derivative free method for its solution. Then, to take into account the presence of nonlinear constraints, we consider the minimization of a new Lipschitz continuous exact penalty function subject to bound constraints. We prove the equivalence of the original inequality constrained problem with the penalized problem subject to bound constraints. In particular, we show that using our derivative free line search approach, global convergence to Clarke-stationary points is guaranteed for the penalized problem. Then, convergence to Clarke-stationary points is also guaranteed for the original constrained problem. We complete our work with a numerical experience on significant test problems, showing the reliability of our proposal.

Kevin Kofler, University of Vienna (with Arnold Neumaier, Hermann Schichl)

Derivative-free optimization with equality constraints using data analysis

This talk will present an algorithm (BBOWDA – Black Box Optimization With Data Analysis) we developed to solve constrained black box optimization problems globally. Our techniques do not require gradients nor direct derivative approximations. Instead, we approximate the functions by a quadratic version of covariance models from data analysis. A particular focus is on constraints: In addition to bound constraints, we also handle black box inequality and equality constraints. In particular, we support equality constraints given in implicit form $f(x) = 0$ where f is a black box function and x a vector of one or more variables. That is achieved by bounding those implicit equality constraints by quadratic approximations using linear programming. We thus obtain surrogate models which we can solve by derivative-based optimization software. Finally, we attempt a heuristic global search by another method from data analysis: We use Gaussian mixture models to locate holes in the search space to fill with sample points. Our approach is particularly tuned for problems where function evaluations are expensive: It requires significantly fewer function evaluations than evolutionary algorithms.

Mjd Powell, University of Cambridge

On derivative-free optimization with linear constraints

The current research of the speaker is on optimization without derivatives when there are linear constraints on the variables. Many features of his NEWUOA software for unconstrained optimization are retained, but it is necessary to include the linear constraints in the subproblem that minimizes the current quadratic model approximately within a trust region. Truncated conjugate gradients is still chosen for solving this subproblem, a restart being made if the usual steplength of an iteration has to be reduced in order to prevent a constraint violation. Each restart gives a smaller subproblem that is regarded as unconstrained after using active constraints to eliminate some of the variables. The active set of the first of these subproblems is chosen carefully, so that the steplength of the first conjugate gradient iteration cannot be made arbitrarily small by the need for feasibility. The progress of this work will be reported, with some preliminary numerical results.

Finance & economics

Tue.1.H 3027

Portfolio optimization

Organizer/Chair John Birge, University of Chicago - Invited Session

Sergio Ortobelli Lozza, University of Bergamo (with valeria caviezel, Tomáš Tichý)

On the impact of some distributional factors in large scale portfolio problems

In this paper, we examine the possibility to estimate the return distributions using a principal component analysis applied to different semidefinite positive correlation matrices. Using a recent classification of semidefinite positive correlation measures we are able to value the impact of different distributional factors in the choices under uncertainty conditions. In particular we investigate the opportunity to reduce

the complexity of large scale portfolio selection problems using some concordance measures. We first analyze the large scale static problem and then we discuss a first extension to the dynamic portfolio problem. Finally we propose an empirical application to the large scale portfolio problem.

Jun-Ya Gotoh, Chuo University (with Keita Shinozaki, Akiko Takeda)

Robust portfolio techniques for coherent risk minimization

Coherent measures of risk have gained growing popularity in financial risk management during the first decade of this century. However, optimal solutions to their minimization are highly susceptible to estimation error of the risk measure because the estimate depends only on a portion of sampled scenarios. In this talk, by employing robust optimization modeling for minimizing coherent risk measures, we present a couple of ways for making the solution robust over a certain range of estimation errors. Specifically, we show that a worst-case coherent risk minimization leads to a penalized minimization of the empirical risk estimate. Besides, inspired by Konno, Waki and Yuuki (2002) we examine the use of factor model in coherent risk minimization. In general, the factor model-based coherent risk minimization along the lines of Goldfarb and Iyengar (2003) is shown to be intractable, and we present a global optimization algorithm for solving the intractable case. Numerical experiment shows that robust approaches achieve better out-of-sample performance than the empirical minimization and market benchmarks.

Romy Shioda, Axioma (with Anureet Saxena, Robert Stubbs)

Factor alignment problem in quantitative portfolio management

The underestimation of risk of optimized portfolios is a consistent criticism about risk models and optimization. Quantitative portfolio managers have historically used a variety of ad hoc techniques to overcome this issue in their investment processes. In this talk, we construct a theory explaining why risk models underestimate the risk of optimized portfolios. We show that the problem is not necessarily with a risk model, but is rather the interaction between alphas, constraints, and risk factors in the risk model. We develop an optimization technique that incorporates a dynamic Alpha Alignment Factor (AAF) into the factor risk model during the optimization process. Using actual portfolio manager backtests, we illustrate both how pervasive the underestimation problem can be and the effectiveness of the proposed AAF in correcting the bias of the risk estimates of optimized portfolios.

Game theory

Tue.1.MA 043

Game-theoretic models in operations

Organizer/Chair Ilan Lobel, New York University · Invited Session

Ilan Lobel, New York University (with Omar Besbes)

Intertemporal price discrimination: Structure and computation of optimal policies

We consider the problem of a firm selling goods over time to customers with heterogeneous patience levels. We let customer valuations be correlated with their willingness-to-wait and look for a dynamic pricing policy that maximizes the long-term revenue of the firm. We prove that the optimal pricing policy is composed of cycles with a period that is at most twice the maximum willingness-to-wait. We also prove that the prices typically follow a nonmonotonic cyclic behavior. Finally, we show that optimizing over dynamic pricing policies can be accomplished in time that is polynomial on the maximum willingness-to-wait among all customers.

Hamid Nazerzadeh, Marshall School of Business

Buy-it-now or take-a-chance: A mechanism for real-time price discrimination

I present a simple sequential mechanism to allocated online advertisement space. The mechanism is motivated by increasingly sophisticated consumer tracking technology that allow advertisers to reach narrowly targeted consumer demographics. Such targeting enhances advertising efficiency by improving the matching quality between advertisers and users, but can also result in thin markets for particular demographic groups.

Georgia Perakis, MIT (with Pavithra Harsha, Zachary Leung)

Markdown optimization for a fashion e-tailer: The impact of returning customers

We study a model for markdown optimization, i.e., how to set prices to maximize revenues from selling a fashion good in the context of an e-tailer. Due to the convenience of Internet shopping, a significant proportion of customers may wait for the price of a fashion item to decrease, strategically returning multiple times to check on the price. This is an important issue that e-tailers need to account for when pricing their

products. In this talk, we propose a model that incorporates returning customer behavior. We focus on the case of a monopolist e-tailer selling a single product over a finite horizon. For classes of demand functions, we develop convex reformulations that are tractable. We derive general insights on pricing strategies in the presence of returning customers. We compare the prices and revenue of a myopic pricing policy, which treats returning customers the same as first-time customers, to the optimal pricing policy. This allows us to estimate the value of smart pricing.

Global optimization

Tue.1.H 2053

Convex optimization approaches to polynomial optimization problems

Organizer/Chair Miguel Anjos, École Polytechnique de Montreal · Invited Session

Amélie Lambert, CEDRIC-Cnam (with Alain Billionnet, Sourour ElIoumi)

Convex reformulations of integer quadratically constrained problems

We consider a general integer program (QQP) where both the objective function and the constraints are quadratic. We show that the quadratic convex reformulation approach can be extended to that case. This approach consists in designing a program, equivalent to QQP, with a quadratic convex objective function and linear or quadratic convex constraints. The resulting program is then solved by a standard solver. We start by dealing with the objective function. For this, we solve a semi-definite program from which we deduce a reformulation of (QQP) as an equivalent problem (P) having a convex quadratic objective function. We then handle the quadratic constraints of (P). We propose and compare linear and quadratic convex reformulations of these constraints. Finally, we give some numerical results comparing our different approaches.

Franz Rendl, AAU Klagenfurt (with Philipp Hungerländer)

Active set methods for convex quadratic optimization with simple bounds

A primal-dual active set method for quadratic problems with bound constraints is presented which extends the infeasible active set approach of Kunisch and Rendl (SIOPT 2003). Based on a guess on the active set, a primal-dual pair is computed that satisfies the first order optimality condition and the complementary condition. Primal variables outside their bounds are added to the active set until a primal feasible solution is reached. Then a new active set is generated based on the feasibility information of the dual variables. Strict convexity of the quadratic problem is sufficient for the algorithm to stop after a finite number of steps with an optimal solution. Computational experience indicates that this approach also performs well in practice.

Janez Povh, Faculty of information studies in Novo mesto (with Gabriele Eichfelder)

On the set-semidefinite representation of nonconvex quadratic programs over arbitrary feasible sets

In the talk we show that any nonconvex quadratic problem over some set $K \subset \mathbb{R}^n$ with additional linear and binary constraints can be rewritten as a linear problem over the cone, dual to the cone of K -semidefinite matrices. We show that when K is defined by one quadratic constraint or by one concave quadratic constraint and one linear inequality, then the resulting K -semidefinite problem is actually a semidefinite programming problem. This generalizes results obtained by Sturm and Zhang (On cones of nonnegative quadratic functions, 2003). Our result also generalizes the well-known completely positive representation result from Burer (On the copositive representation of binary and continuous nonconvex quadratic programs, 2009), which is actually a special instance of our result with $K = \mathbb{R}_+^n$. In the last part of the talk we present new approximation hierarchies for the cone of copositive matrices based on the completely positive moment matrices.

Implementations & software

Tue.1.H 1058

MILP software II

Organizer/Chair Thorsten Koch, ZIB · Invited Session

Martin Tieves, RWTH Aachen (with Arie Koster, Manuel Kutschka)

Creating synergies between MIP-solvers

Mixed integer programming offers a broad field of interest for both, research and application. Therefore a wide range of MIP solvers is available, each with its own advantages and disadvantages. In this paper we analyze the potential of combining different solvers and/or different parameter settings in a parallel computation. Hereby, we focus on combinations of the solvers SCIP, CPLEX and GUROBI extended with different

strategies of searching in the branch and bound tree. These solvers are run as blackbox-solvers on parallel threads, exchanging potential information as primal solutions or dual bounds via callbacks at runtime. We apply the above on the MIPLIB data-sets and show a promising speed-up in computation for many instances.

Michael Joswig, TU Darmstadt (with Ewgenij Gawrilow)

polymake for integer linear programming

polymake is a software tool for experiments in polytope theory and related areas. More recently, new functionality useful for integer linear programming was added. This includes Hilbert bases (via interface to Normaliz), Gomory-Chvátal closures, lattice point enumeration, standard constructions, and more.

The system has been developed since 1997 and continuously expanded. Many people contributed over the years, see <http://www.polymake.org/doku.php/team> for the complete list.

See also a new tutorial related to optimization by Marc E. Pfetsch and Sebastian Pokutta: <http://www.polymake.org/doku.php/tutorial/optimization>

Frédéric Gardi, LocalSolver (with Thierry Benoist, Julien Darlay, Bertrand Estellon, Romain Megel, Karim Nouioua)

LocalSolver: A mathematical programming solver based on local search

We present LocalSolver 2.0 (<http://www.localsolver.com>), a mathematical programming solver founded on local-search techniques. LocalSolver offers simple APIs as well as an efficient modeling language for fast prototyping. Actually, it is designed to tackle combinatorial problems, that is, models with 0-1 decision variables only. LocalSolver can handle very large nonlinear problems with millions of binary decisions in minutes of running times only. Its practical performance relies on innovative autonomous moves coupled with a highly-optimized incremental evaluation machinery. In this way, LocalSolver is able to explore millions of feasible solutions in minutes of running times, ensuring a fast convergence toward high-quality solutions. It has been tested on classical benchmarks and succeeded the first phase of the Google ROADEF/EURO Challenge (ranked 25th among 80 participating teams). Moreover, LocalSolver is used in several real-life applications: TV media planning, maintenance planning, energy optimization, mobile network partitioning, car sequencing, project management. For the next version, we plan to extend its capabilities to deal with mixed-variable models.

Integer & mixed-integer programming

Tue.1.H 2013

MILP formulations III

Chair Magnus Önnheim, Chalmers University of Technology

Ramiro Torres, Escuela Politécnica Nacional (with Diego Recalde, Polo Vaca)

Optimizing the Ecuadorian football league third division.

In this work, a real-world application arising in the Ecuadorian football league third division is considered. Currently, this league is played by a set of teams which is empirically partitioned by a geographical nearness criterion. After identifying such partition, teams on each group play an independent double round robin tournament.

The problem consists in partitioning the set of teams into groups such that the distance travelled by each team in away-matches is minimized. Moreover, the number of teams in a group is fixed by regulations of the football league. Balanced groups, according to football level, are desired and other aspects like rivalry between teams and geographical constraints must be considered. An integer programming approach is proposed to solve this problem. Computational experiments are performed, where instances provided by the Ecuadorian Football Federation can be solved quite well, and significant improvements compared with the current situation are shown.

Keisuke Hotta, Bunkyo University

Enumeration and characterization of the electoral districting for the decision support

In Japan, 300 members of the House of Representatives, the Lower House, are elected by the single-seat constituency system. Each electoral district is made by the apportionment to the 47 prefectures and the redistricting in each prefecture. The apportionment gives the lower bound of the gap in the value of individual votes. Because of the density of population in an urban area, the lower bound of the ratio is close to 2 times. As a result, the gap is more than 2 by the redistricting. In Japan, the state of the same condition has been continuing for over ten years. By optimizing both the apportionment problem and the redistricting problems respectively, the limit of the disparity is 1.939 for the population in 2010 and the provinces in 2011. The 0–1 IP model to optimize the redistricting was studied by Nemoto and Hotta in 2003. The optimal

district gives the limit of the disparity, but it is not always practical. So, it is better to enumerate some practical district, to point out the similarity to the current district, and to characterize the district candidates. This research provides them for the decision support.

Magnus Önnheim, Chalmers University of Technology (with Torgny Almgren, Niclas Andréasson, Michael Patriksson, Ann-Brith Strömberg, Adam Wojciechowski)

The opportunistic replacement problem: Model, theory and numerics

We present a 0–1 integer linear programming (ILP) model for determining optimal opportunistic maintenance schedules for a system of components with maximum replacement intervals; it is a natural starting point for modelling replacement schedules of more complex systems. We show that this problem is NP-hard and that all the necessary inequalities induce facets. We further present a new class of facets defined by $\{0, \frac{1}{2}\}$ -Chvátal-Gomory cuts. For costs monotone with time a class of elimination constraints, allowing for maintenance only when replacement is necessary for at least one component, is defined. For fixed maintenance occasions the remaining linear program is solvable by a greedy procedure.

Results from a case study on aircraft engine maintenance illustrate the advantage of the 0–1 ILP model over simpler policies. We include the new class of facets in a branch&cut framework and note a decrease in number of branch&bound nodes and simplex iterations for most instance classes with time dependent costs. For instance classes with time independent costs and few components the elimination constraints are used favourably.

Integer & mixed-integer programming

Tue.1.H 2032

Trends in mixed integer programming II

Organizers/Chairs Andrea Lodi, University of Bologna; Robert Weismantel, ETH Zurich · Invited Session

Gustavo Angulo, Georgia Institute of Technology (with Shabbir Ahmed, Santanu Dey)

Semi-continuous network flow problems

We consider network flow problems where some of the variables are restricted to be semi-continuous. We introduce the single-node semi-continuous flow set with variable upper bounds as a relaxation. Two particular cases of this set are considered, for which we present complete descriptions of the convex hull in terms of linear inequalities and extended formulations. We study the efficacy of the polyhedral results on a class of semi-continuous transportation problems.

Domenico Salvagnin, University of Padova (with Matteo Fischetti, Michele Monaci)

Randomness and tree search

Many mixed integer linear programs exhibit a high performance variability when solved with current state-of-the-art solvers, meaning that seemingly performance-neutral changes in the environment or in the input format have a great influence in the actual solution process.

Such variability is intrinsic in the enumerative nature of the branch-and-cut methods used to solve MIP instances and is mainly due to the fact that many decisions taken during the tree search (e.g., branching strategies, primal heuristics) are just heuristics and are subject to imperfect tie-breaking (degeneracy of the instance at hand further complicates the picture).

We investigate whether randomness can be a useful tool to overcome the issue of performance variability and to actually take advantage of it to speed up the solution process. Preliminary computational results show that the proposed approach is promising.

Stefano Smriglio, University of L'Aquila (with Andrea Lodi, Ted Ralphs, Fabrizio Rossi)

Interdiction branching

Interdiction branching is a branching method for binary integer programs that is designed to overcome some difficulties that may be encountered by branching on a variable dichotomy. Unlike traditional methods, the branching disjunction is selected taking into account the best feasible solution found so far. In particular, the method computes an improving solution cover, which is a set of variables of which at least one must be nonzero in any improving solution. From an improving solution cover, we can obtain a branching disjunction such that each child node is guaranteed to contain at least one improving solution. Computing a minimal improving solution cover amounts to solving a discrete bilevel program, which is difficult in general. In practice, a solution cover, although not necessarily minimal nor improving, can be found using a heuristic that achieves a profitable trade-off between the size of the enumeration tree and the computational burden of computing the cover. An empirical study shows that such an implementation of the method reduces significantly the size of the enumeration tree compared to branching on variables.

Integer & mixed-integer programming

Tue.1.MA 042

Non-standard optimization methods

Chair Dennis Egbers, Technische Universität Braunschweig

Roman Polyak, George Mason University

Nonlinear equilibrium for optimal resource allocation

When linear programming (LP) is used for optimal allocation limited resources the prices for goods and the resources availability are given priority and independent on the production output and prices for the resources. Nonlinear equilibrium (NE) eliminates this basic drawback of LP allowing finding prices for goods and resources availability consistent with the production output and prices for the resources. Finding NE is equivalent to solving a variation inequality (VI) on the Cartesian product of the primal and dual non negative octants, projection on which is a very simple operation. We consider two methods: projected pseudo-gradient (PPG) and extra pseudo-gradient (EPG), for which the projection on the feasible set is the main operation. Both PPG and EPG can be viewed as pricing mechanisms for establishing economic equilibrium. We established convergence, proved global Q -linear rate and estimated complexity of both methods under various assumptions on the input data.

Dennis Egbers, Technische Universität Braunschweig (with Satoru Fujishige, Uwe Zimmermann)

Some remarks on the LP-Newton method

Nowadays it is well known that linear programming problems can be solved in weakly polynomial time. Still unresolved is the question whether there exists a strongly polynomial algorithm for linear programming or not. In 2009 Fujishige discussed some alternative approach inspired by successful application in submodular optimization in order to achieve some advancement in this direction which stimulated our research.

As shown by, i.e., Papadimitriou and Stieglitz, linear programming problems may w.l.o.g. be considered to be bounded. It is possible to reduce bounded LP to a sequence of LPs on zonotopes which can easily be solved by a greedy algorithm. The approach presented is based on the zonotope formulation and can be described as a Newton-type algorithm using a sequence of minimum norm point calculations iterating to the optimum. Based on previous work by Fujishige et al. we will present theoretical as well as practical results on the performance of the algorithm. In particular, different approaches for calculating the minimum norm point will be compared with respect to certain drawbacks in a previously applied algorithm of Wolfe.

Life sciences & healthcare

Tue.1.H 2033

Bioinformatics and combinatorial optimization I

Organizers/Chairs Rumen Andonov, INRIA and University of Rennes 1; Carlile Lavor, State University of Campinas · Invited Session

Zachary Voller, Iowa State University (with Zhijun Wu)

An optimal solution to the generalized distance geometry problem

NMR experiments on a protein yield a set of inter-atomic distance ranges. A number of structures satisfying the distance constraints, derived from distance range and bond information, are then generated. This ensemble of structures is often under represented and inaccurately represents the protein's structural fluctuations. In this presentation we present an alternative problem where its solution, derived from interior point optimization, provides a single representation for a protein's conformation and its ensemble of possible structures.

Antonio Mucherino, IRISA (with Luiz Carvalho, Virginia Costa, Carlile Lavor, Nelson Maculan)

Re-ordering protein side chains for the discretization of MDGPs

We consider a class of Molecular Distance Geometry Problems (MDGPs) that can be discretized in the hypothesis some assumptions are satisfied. We refer to this class of problems as the Discretizable MDGP (DMDGP). The discretization assumptions are strongly depend upon the ordering that is associated to the atoms of the considered molecules. In a recent work, we proved that any MDGP related to protein backbones can be discretized if the backbone atoms are re-arranged by considering a special ordering we identified. In this work, we investigate the possibility to find such discretization orderings for the side chains of the amino acids involved in the protein synthesis.

Martin Gebser, University of Potsdam (with Carito Guziolowski, Mihail Ivanchev, Torsten Schaub, Anne Siegel, Sven Thiele, Philippe Veber)

Repair and prediction (under inconsistency) in large biological networks with answer set programming

We address the problem of repairing large-scale biological networks and corresponding yet often discrepant measurements in order

to predict unobserved variations. To this end, we propose a range of different operations for altering experimental data and/or a biological network in order to re-establish their mutual consistency and thus to enable automated prediction. For accomplishing repair and prediction, we take advantage of the distinguished modeling and reasoning capacities of Answer Set Programming. We validate our framework by an empirical study on the widely investigated organism *Escherichia coli*.

Logistics, traffic, and transportation

Tue.1.H 0106

Routing with time windows

Chair Paul Stursberg, TU München

Juan Otero, Havana University (with Erick Lanford)

A hybrid evolutionary approach for solving the vehicle routing problem with time windows (VRPTW)

In this paper an evolutionary strategy for solving the VRPTW is proposed. The main idea of this approach is to use routing constructive heuristics for generating the initial population and for designing the genetic operators. Modifications of the push forward insertion heuristic [2] and of an efficient insertion heuristic proposed by Campbell and Savelsbergh [1] are introduced. Both algorithms are used in an adequate proportion, depending on the number of customers, in order to combine the simplicity of the first and the high performance of the second one. In order to analyze the behavior of the proposed approach, it was programmed in C#. Computational tests were performed, using ten problems of the Gehring/Homberger library. The results were very similar to the best solutions reported in the literature and, for some problems, the obtained solutions are the best known so far.

- [1] A. Campbell, M. Savelsbergh, "Efficient insertion heuristics for vehicle routing and scheduling problems". *Transportation Science* Vol. 38, No. 3.
- [2] M. Solomon, "Algorithms for the vehicle routing and scheduling problem with time windows constraints". *Operations Research* 35, 1987.

Tiago Montanher, Mathematics and Statistics Institute of University of São Paulo

An integer programming model for the oil transference in refineries under time window constraints

Programmers of oil refineries often face the problem of moving their commodities between tanks. The transference is made through a shared pipeline network. Each pipeline can take only one transference at time which has costs due to degradation and safety issues. The programmer also needs to consider delivery times at each destination which is usually expressed in terms of a time window. We model this scenario as the problem to find k -vertex disjoint paths in a graph under time window constraints. Here k is the number of transferees. Each edge (pipeline) has a cost and a transfer time depending on the commodity transferred. We ask for independent paths to satisfy time constraints while minimizing total transference costs. Our formulation leads to a branch and price algorithm which combines an integer programming model with a Dantzig Wolfe decomposition reformulation in order to treat time constraints. We show numerical results in a real but simplified plant with 117 equipments, 230 pipelines and a variable number of simultaneous transferees.

Paul Stursberg, TU München (with René Brandenburg, Michael Ritter)

Vehicle routing with flexible load carriers

In many Vehicle Routing applications, using containers allows to shorten loading times and compose (potentially more efficient) tours more flexibly. We examine the optimization problem that occurs in settings, where a small number of containers is used to fulfill transportation tasks on a graph. To derive an ILP model, we consider a graph, where each task is represented by a vertex and arcs correspond to tasks directly succeeding each other. Now, the problem is related to the Vehicle Routing Problem with Time Windows, but constraints added to account for container usage render common decomposition approaches more or less useless. Instead, we can embed the problem into a broader framework which encompasses applications from routing on a multi-graph to Airline Crew Scheduling. The framework uses of a number of independent transportation layers which passengers can travel on and change between to fulfill certain objectives. This approach motivates a new model which treats containers as passengers in the described framework, thus circumventing major deficiencies of the original model, significantly decreasing its size and allowing a number of new instances to be solved to optimality.

Logistics, traffic, and transportation

Tue.1.H 0111

Green maritime transport logistics

Organizer/Chair Harilaos Psarrafis, National Technical University of Athens · Invited Session

Harilaos Psarrafis, National Technical University of Athens (with Christos Kontovas)

Speed optimization in a ship pickup and delivery problem: balancing economic and environmental performance

We consider a single ship pickup and delivery problem with multiple origins and multiple destinations, in which ship speed is one of the decision variables. Each port can be visited as many times as necessary so as to pick up and deliver cargoes originating from it and destined to it. These operations can be combined in a single port stop if this is warranted. Cargoes to or from distinct ports can co-exist on the ship, so long as ship capacity is not exceeded. Cargoes cannot be split. Costs include fuel, vessel charter and in-transit cargo inventory costs. In general, different speeds can be chosen for different legs of the route, so long as they are between known lower and upper bounds. Both bounds are dictated by the maximum power and technology of the engine, and by ship payload. Fuel consumption is a known function of ship speed and ship payload. It can be shown that on each leg of the route the speed decision can be decomposed from the pickup and delivery decision. We develop algorithms that optimize the ship's route and we compare minimum cost solutions with minimum emissions solutions. Several scenarios are examined and computational experience is reported.

Haakon Lindstad, NTNU - MARINTEK

Scheduling and environmental routing of maritime vessels in a multiobjective environment

Shipping companies must manage their fleets effectively in order to stay in business. Ship scheduling and routing which concerns the optimal assignment of available cargoes to maximize profit is a complex problem that may play an important role in this respect. Increased environmental concern due to climate change adds another dimension to the scheduling and makes it multi objective. This study has focused on developing a methodology for calculating emissions and cost as function of sea conditions and vessel characteristics. The developed methodology has been used for scheduling and optimization with multi objective voyage priorities such as minimizing voyage emissions, minimizing voyage cost and maximizing profit.

Orestis Schinas, Hamburg School of Business Administration HSBA (with Christos Stefanakos)

The cost of SOx limits to marine operators: Results from exploring marine fuel prices

Marine operators are confronted with the new air emissions regulations, that determine the limits of sulphur content in marine fuels. The low-sulphur (LS) marine fuels have a higher price, and their fluctuation is almost similar to the fluctuation of high-sulphur (HS) fuels. The price difference between HS and LS might also determine the decision of operators for alternative technical means, such as scrubbers, in order to comply with the new limits. This paper aims to provide a thorough statistical analysis of the currently available LS and HS marine fuels time series, as well as to present the analysis of the differential of the HS and LS fuel prices. Moreover, forecasting issues are discussed on the basis of the conventional analysis tools vis-a-vis a fuzzy forecasting methodology. The results of the comparison could guide the next steps of research.

Mixed-integer nonlinear programming

Tue.1.MA 005

Efficient solvers for mixed integer nonlinear optimization problems

Organizers/Chairs Leo Liberti, École Polytechnique; Pietro Belotti, Clemson University · Invited Session

Stefan Vigerske, GAMS Software GmbH

Solving MINLPs with SCIP

We discuss recent extensions of the constraint integer programming framework SCIP for solving mixed-integer nonlinear programs. Nonlinear constraints (convex or nonconvex) are handled within an LP-based branch-and-cut algorithm by reformulation, linear relaxation, and domain propagation. In an extensive computational study, we compare the performance of our implementation with state-of-the-art solvers for MINLP and analyze the impact of various solver components on the overall performance.

Pietro Belotti, Clemson University

Separation of valid inequalities for multilinear functions

We develop efficient methods to separate valid inequalities for a set defined by a multilinear function, i.e., a function that is linear when all variables but one are fixed. One method takes advantage of a tensor representation of a multilinear term, while the other uses a divide-and-conquer technique coupled with dynamic programming in order to find

the most violated inequality. Some preliminary experimental results are reported.

Hongbo Dong, University of Wisconsin-Madison

On box constrained quadratic programming with binary indicators

We consider (nonconvex) quadratic programming with box constraints and binary variables that are the "on/off" switches for continuous variables. We prove some geometric results on the corresponding convex hull, and show how to lift a class of valid inequalities for Box QP to include binary indicators. We prove that the separation problem for these lifted cuts is polynomially solvable, as long as the number of binary variables included are not too many. Finally computational results will be reported to verify the effectiveness of these cuts.

Multi-objective optimization

Tue.1.H 1029

Multiobjective optimization II

Chair Nasim Nasrabadi, Birjand University, Aalto University

Thomas Stidsen, Technical University of Denmark (with Christopher Ryther)

A branch & cut algorithm for bi-objective TSP

Branch & cut algorithms were invented to solve TSP and have since become the standard approach to solve MIP's. In this presentation we will present a branch & cut algorithm for TSP's with two cost matrices. The solution to the TSP with two objective functions is not one optimal tour, but the set of all Pareto optimal tours. A Pareto optimal tour is a tour that no other tour exist which is better on one of the objectives and better or equal on the other objective. We will briefly review why the bi-objective TSP is a very hard optimization problem. Then we will present our branch & cut algorithm, which can find the Pareto optimal set of tours. Using cuts from The Concorde code in our branch & cut algorithm we are able to solve bi-objective TSP problems with up to 120 cities. This has to the best of our knowledge never been done before.

Gulsah Karakaya, Middle East Technical University (with Murat Koksalan)

Decision support for multi-attribute multi-item reverse auctions

In this study, we address multi-item auction problems in a multi-attribute, multi-round reverse auction setting. In each round, we provide the buyer with a set of efficient bid combinations, who then chooses the provisional winners whose bids collectively provide all the required items. We estimate preference information from the buyer's choices and provide this to the bidders. The bidders update/improve their bids in order to become/stay competitive. The process continues several rounds. The developed interactive approach tries to have the more competitive bidders eventually end up winning the auction.

Nasim Nasrabadi, Birjand University, Aalto University (with Akram Dehnohalaji)

Non-radial models to define the preference measure for convex cone-based strict partial order

Multiple Criteria Decision Making (MCDM) is an important field in applied mathematics. The main goal in MCDM is finding the most preferred solution among a set of alternatives or to rank order them. We consider the problem of finding a strict partial order for a finite set of multi-criteria alternatives. We assume an unknown quasi-concave value function and the DM's preferences are available in the form of pair-wise comparisons. Then, a polyhedron and a convex cone are constructed such that the vertex of the cone is an inferior alternative. To produce a rank order, we determine the status of an arbitrary alternative w.r.t. the vertex of the cone by solving two Linear programming (LP) problems. A similar study has been done by Dehnohalaji et al. The main difference is that they built the two LPs based on a radial distance. However, the radial measure has some drawbacks, especially in the case that the data are large, the results would not be much informative. Also, the radial measure is unstable when small changes occur in the data set of the problem. Therefore, the new non-radial models solves the drawbacks and concludes more reliable results.

Nonlinear programming

Tue.1.H 0107

Methods for nonlinear optimization IV

Chair Hans-Bernd Dürr, University of Stuttgart

Charlotte Tannier, University of Namur (FUNDP) (with Daniel Ruiz, Annick Sartenaer)

Block diagonal preconditioners using spectral information for saddle-point systems

For nonsingular indefinite matrices of saddle-point (or KKT) form, Murphy, Golub and Wathen (2000) have shown how preconditioners incorporating an exact Schur complement lead to preconditioned matrices with exactly two or exactly three distinct eigenvalues. Focusing on symmetric matrices with a positive definite $[1, 1]$ block and a zero $[2, 2]$

Nonlinear programming

block, we consider the case where the saddle-point system is very badly conditioned due to the combined effect of very small eigenvalues of the $(1, 1)$ block and of very small singular values of the off-diagonal block. Under the assumption that spectral information related to these very small eigenvalues/singular values can be extracted separately, we propose and study different approximations of the “ideal” block diagonal preconditioner of Murphy, Golub and Wathen (2000) with exact Schur complement, based on an approximation of the Schur complement that combines the available spectral information. We also derive a practical algorithm to implement the proposed preconditioners within a standard minimum residual method and illustrate the performance through numerical experiments on a set of saddle-point systems.

Hans-Bernd Dürr, University of Stuttgart (with Christian Ebenbauer)

Continuous-time saddle point algorithms with applications in control

We present some recent results on a novel class of smooth optimization algorithms that compute saddle points which arise in convex optimization problems. In contrast to many related results, we are dealing with optimization algorithms which are formulated as ordinary differential equations, i.e. as smooth continuous-time vector fields, which we analyze from a dynamical systems theory perspective. The idea of using a differential equations to find a saddle point of a Lagrangian function goes back to K. J. Arrow, L. Hurwicz and to H. Uzawa. They proposed a gradient-like vector field (AHU-flow) with a non-smooth operator. An alternative vector field for saddle point problem is presented in this work. Like the AHU-flow, its trajectories are converging to the saddle point of the Lagrangian. However, this vector field has two distinct features. First, we prove that the flow also converges for linear programs, which is not the case for the AHU-flow, and second, the vector field is smooth which can be exploited in control theory to design distributed feedback laws for multi-agent systems. Furthermore, the convergence of a continuous-time Nesterov-like fast gradient variant is proved.

Nonlinear programming

Tue.1.H 0110

Nonlinear optimization IV

Organizers/Chairs Frank E. Curtis, Lehigh University; Daniel Robinson, Johns Hopkins University · Invited Session

Jaroslav Fowkes, University of Edinburgh (with Coralía Cartis, Chris Farmer, Nicholas Gould)

Global optimization of Lipschitz continuous functions

We present a branch and bound algorithm for the global optimization of a twice differentiable nonconvex objective function with a Lipschitz continuous Hessian over a compact, convex set. The algorithm is based on applying cubic regularization techniques to a radial-basis model of the objective over balls that form an overlapping covering of the feasibility domain. Numerical results for both serial and parallel implementations will be provided.

Roger Fletcher, Dundee University

On trust regions and projections for an SLCP algorithm for NLP

The speaker has recently developed a first derivative trust region filter algorithm for NLP (SIOPT Darmstadt 2011) based on successive linear constraint programming (SLCP) (Robinson’s method). Open source code is available through COIN-OR. Numerical evidence suggests that it is comparable in run time to the second derivative code filterSQP. An important feature of the code is the occasional use of projection steps to control feasibility violations, which can significantly improve the speed of (global) convergence on some highly nonlinear problems.

Discussions with other researchers have identified a possible area for improvement in that these projection steps take no account of the objective function value, in contrast say to second order correction (SOC) steps. The speaker has been investigating the possibility of replacing projection steps by additional LCP calculations. New insight is provided as to how a trust region might be designed to operate in an NLP context. Early indications are that significant gains in both speed and reliability may be possible, both in feasibility restoration and in finding local optimality. There are also indications for proving global convergence.

Jennifer Erway, Wake Forest University

Quasi-Newton methods for solving the trust-region subproblem

In this talk, we consider quasi-Newton trust-region methods for large-scale unconstrained optimization. A new trust-region subproblem solver is proposed that is able to take advantage of the special structure of quasi-Newton approximations to Hessians. The method relies on a sequence evolving, low-dimensional subspaces. Numerical results compare the proposed method with other popular quasi-Newton trust-region methods in various trust-region settings.

Tue.1.H 0112

Real-time optimization I

Organizers/Chairs Victor Zavala, Argonne National Laboratory; Sebastian Sager, Universität Magdeburg · Invited Session

Hans Joachim Ferreau, KU Leuven (with Moritz Diehl, Rien Quirynen, Milan Vukobratović)

The ACADO code generation tool for high-speed model predictive control and moving horizon estimation

Model predictive control (MPC) is an advanced feedback control strategy that predicts and optimises the future behaviour of a dynamic system in real-time. This requires full knowledge of the current system state, which typically needs to be estimated from noisy measurements, e.g., by means of moving horizon estimation (MHE). Both MPC and MHE require to solve a constrained, nonlinear optimisation problem in real-time, possibly on slow embedded hardware. The recently proposed ACADO Code Generation tool allows the user to automatically export nonlinear real-time iteration algorithms that are customised based on a symbolic MPC/MHE problem formulation. This talk presents major algorithmic extensions of this tool: First, it now also handles dynamic systems described by differential algebraic equations. Second, not only explicit but also implicit Runge-Kutta integrators can be exported now. Third, auto-generated sparse quadratic programming solvers have been added for speeding-up solution in case of long prediction horizons. We illustrate the efficiency of the exported MPC/MHE algorithms by controlling small-scale but challenging nonlinear systems at sampling times of a few milliseconds.

Janick Frasch, Interdisciplinary Center for Scientific Computing (IWR), University of Heidelberg (with Hans-Georg Bock, Sebastian Sager, Leonard Wirsching)

Fast mixed-level iteration schemes for nonlinear model predictive control on multicore architectures

Nonlinear model predictive control (MPC) algorithms generally require the (approximate) solution of a nonlinear program (NLP) at each sampling time for feedback generation. Providing sufficiently high feedback rates therefore poses a major computational challenge for systems with fast dynamics. Recent approaches to overcome this challenge extend the multiple shooting-based real-time iteration scheme to multi-level iteration schemes. These algorithms generate feedback by repeatedly solving a quadratic program (QP), updating its data parts – constraint residuals, gradients, and Hessians and constraint Jacobians of the NLP – on three levels of increasing computational complexity. In this contribution we consider mixed-level updates of the QP data, which intervalwise apply different update levels. In particular we apply higher-level updates more frequently on the first intervals of the control horizon, given their importance in the MPC context. Targeting at modern computers with multi-core processing units, we describe an efficient parallel implementation of the mixed-level iteration approach and apply it to a benchmark problem from automotive engineering.

Moritz Diehl, KU Leuven (with Hans Joachim Ferreau, Attila Kozma)

Real-time optimization of large distributed systems

When large interconnected systems shall be optimally operated using model-based optimization, it is desirable to have parallelism in the used algorithms as well as decentralized decision making. As decentralized decision making with only vector exchanges leads to extremely slow linear or even sublinear convergence rates to the centrally optimal solution, we focus on parallelism with decentralized data storage, but coordinated decision making.

In particular, we discuss the distributed multiple shooting (DMS) method that allows one to decompose large-scale optimal control problems in both space and time and to completely parallelize the expensive function and derivative generation in shooting methods. Due to their superior warm starting capabilities in the real-time context, we focus on SQP type methods. Here, the QP solution is the only part of the algorithm that is not trivial to distribute, and we discuss several strategies for distributed QP solution and compare their convergence properties and warm starting capabilities.

Nonsmooth optimization

Tue.1.H 1012

Nonsmooth optimization in imaging sciences II

Organizer/Chair Dirk Lorenz, TU Braunschweig · Invited Session

Michael Goldman, CMAP Polytechnique

Continuous primal-dual methods for image processing

In image processing, variational models are widespread. Tackling numerically these models is still a challenging problem. Among the existing methods, the primal-dual methods are some of the most efficient. They are however still not well understood. The aim of this work is to study the continuous primal-dual method proposed by Appleton

and Talbot. This study gives a new insight on this approach and yields original a posteriori estimates.

Elias Helou, University of São Paulo (with Álvaro De Pierro)

Incremental subgradients for constrained convex optimization: A unified framework and new methods

We will present a unifying framework for nonsmooth convex minimization bringing together ϵ -subgradient algorithms and methods for the convex feasibility problem. This development is a natural step for ϵ -subgradient methods in the direction of constrained optimization since the Euclidean projection frequently required in such methods is replaced by an approximate projection, which is often easier to compute. The developments are applied to incremental subgradient methods, resulting in new algorithms suitable to large-scale optimization problems, such as those arising in tomographic imaging.

The flexibility of the framework will be demonstrated by the presentation of several operators, both for the optimality step and for the feasibility step of the prototypical algorithm.

Jerome Fehrenbach, ITAV

Stripes removal in images, applications in microscopy

In a number of imaging modalities, images are degraded by a noise composed of stripes. This is the case, e.g., in Atomic Force Microscopy, in nanotomography or in Selective Plane Illumination Microscope (which is an emerging imaging modality). This work aims at proposing an efficient method to restore these images. A model of stationary noise is presented, where the noise is defined as the convolution of a given pattern with a white noise. The denoising problem is then formulated using a Bayesian approach. It leads to a non-smooth convex optimization problem. The minimization is performed using a preconditioned primal-dual algorithm proposed by Chambolle and Pock in 2011. Our framework allows to take into account several components of noise, and the proposed algorithm can simultaneously remove stripes and Gaussian white noise. Results on images obtained using different modalities are presented, using a Total Variation prior on the space of images. A plugin for the open source FIJI software is available.

Optimization in energy systems

Tue.1.MA 549

Multi-stage stochastic programming models for electricity systems

Organizer/Chair Andy Philpott, University of Auckland - Invited Session

Vitor de Matos, Plan4 (with Ertan Finardi, Andrew Philpott)

On solving multistage stochastic programs with general coherent risk measures

In this work we discuss the solution of multi-stage stochastic linear programs with general coherent risk measures, using sampling-based algorithms such as stochastic dual dynamic programming (SDDP). We describe a computational approach that changes the probability measure of the outcomes of next stage problems to compute the outer approximation of the future cost function (cuts in SDDP). This provides a lower bound on the certainty-equivalent value of the optimal policy, and requires little modification of conventional algorithms. We provide a new convergence test for this class of risk-averse problems by computing an upper bound on the certainty-equivalent value of the optimal policy, using an inner approximation algorithm. Finally, we show the results of computations on a large scale problem (the Brazilian long term hydrothermal scheduling problem), in which we compare the proposed implementation strategy with the one used previously by these authors.

Pierre Girardeau, EDF R&D - University of Auckland (with Andrew Philpott)

Modelling electricity prices and capacity expansions over a long-term horizon

We consider a power producer who wants to minimize in the long-term the sum of its production costs and investment costs. We make a distinction between two sorts of randomness: "Day-to-day randomness" that affects the system, like power demand, water inflows, etc. and more "sporadic randomness" like political decisions (recently Germany decided to stop nuclear power production), long-term fuel prices trends, etc. These two kinds of randomness are treated differently.

Unlike most existing approaches which consider two-step problems, our model is a multi-stage stochastic MIP and thus allows us to obtain investment strategies rather than simple decisions. However, this program is too big to be solved directly by a commercial solver. Hence we develop a specific Dantzig-Wolfe decomposition scheme that consists in the iterative resolution of yearly subproblems coordinated by a master problem that ensures satisfaction of the non-anticipativity constraints and, in the end, optimality of the solution.

We show an experiment on the real-life problem of choosing gen-

eration and transmission investments for the New Zealand electricity system.

Kengy Barty, EDF R&D, OSIRIS dept (with Anes Dallagi, Arnaud Lenoir)

A quantities decomposition scheme for energy management

Each country in the European electricity market has its own way to cope with its electricity demand. The utilities perform strategies that minimize their production cost under technical constraints together with information constraints. They can use to supply consumer's demand, various electricity generation units together with market offers. The problem for each actor is to schedule its generation and determine whether or not he has to import/export electricity. The countries are linked through the electricity grid, we propose a decomposition scheme that iterates over the interconnection flows. This scheme allows flexibility to build subproblems. We are going to present the algorithm and we are going to show how it behaves.

Optimization in energy systems

Tue.1.MA 550

Nonlinear and combinatorial aspects in energy optimization

Organizer/Chair Antonio Frangioni, Università di Pisa - Invited Session

Sofia Zaourar, Inria Grenoble (with Jérôme Malick)

Prices stabilization for inexact unit-commitment problems

Unit-commitment (UC) problems in electricity production are well-suited for constraint (or price) decomposition techniques: by dualizing the linking constraints, the large-scale nonconvex problem decomposes into smaller independent subproblems. The dual problem consists then in finding the best Lagrangian multiplier (the optimal price); it is solved by a convex nonsmooth optimization method.

Realistic modeling of technical production constraints makes the Lagrangian subproblems themselves difficult to solve. It is possible for bundle algorithms to cope with inexact solutions of the subproblems. In this case however, the computed optimal dual variables show a noisy and unstable behaviour, that could prevent their use as price indicator.

In this talk, we present a way to stabilize dual optimal solutions by penalizing the noisy behaviour of the prices in the dual objective. After studying the impact of a general stabilization term on the model and the resolution scheme, we present total variation stabilization and its primal interpretation. We illustrate our approach on the real-life UC problem of Electricite de France (French Electricity Board).

Antonio Frangioni, Università di Pisa (with Claudio Gentile)

Exploiting structure in MIQP approaches to unit commitment problems

The unit commitment problem in electrical power production is naturally formulated as a mixed-integer quadratic program; as such it could be solved with general-purpose MIQP tools, but direct application of this approach using the standard formulation is not efficient. Yet, the problem presents several (possibly nested) sources of structure, from the space decomposability usually exploited by Lagrangian Relaxation approaches (leading to smaller, very structured MIQP subproblems for which efficient specialized methods exist) to the presence of very many semicontinuous variables with convex nonlinear cost (which suggests the use of perspective reformulation techniques to strengthen the lower bound). We discuss novel ways of exploiting some of these structures, possibly in combination, reporting computational results to help gauging their potential effectiveness.

Maria Teresa Vespucci, University of Bergamo (with Alberto Gelmini, Mario Innorta, Diana Moneta, Dario Siface)

A procedure for minimizing variations of an initial operating point in medium-voltage AC network with distributed generation and storage devices

An optimization algorithm is described for the voltage control of medium voltage distribution networks in presence of distributed generation. Given the current operating point and the forecasted load and generation, the algorithm computes the changes to be requested to the controllable resources in order to ensure fulfillment of technical constraints (voltage at nodes, current in branches) with the lowest overall cost. Distributor's redispatching costs, modelled by means of binary variables, are minimized while satisfying service security requirements and ensuring service quality, represented by nonlinear constraints. Storage devices are modeled by means of constraints that relate adjacent time periods. The proposed two-step solution procedure is based on decoupling active and reactive variables. In step 1 a MILP model determines the active power production and the use of storage devices that minimize redispatching costs over all periods in the time horizon: in this step a DC network representation is used. In step 2, given the optimal active power productions computed in step 1, reactive variables in each time period are computed by solving an AC optimal power flow model.

PDE-constrained opt. & multi-level/multi-grid meth.

Tue.1.MA 415

Adaptive methods in PDE constrained optimization

Organizer/Chair Stefan Ulbrich, TU Darmstadt · Invited Session

Winnfried Wollner, Universität Hamburg

Adaptive finite element discretizations in structural optimization

In this talk we will consider a prototypical example from structural optimization. Namely the well known compliance minimization of a variable thickness sheet, i.e., given a domain $\Omega \subset \mathbb{R}^2$, we consider

$$\min_{q \in L^2, u \in H_D^1} l(u)$$

subject to the constraints

$$\begin{aligned} (q \sigma(\nabla u), \nabla \phi) &= l(\phi) \quad \forall \phi \in H_D^1(\Omega; \mathbb{R}^2), \\ 0 &< q_{\min} \leq q \leq q_{\max}, \\ \int_{\Omega} q &\leq V_{\max}, \end{aligned}$$

where $H_D^1(\Omega; \mathbb{R}^2)$ denotes the usual H^1 -Sobolev space with certain Dirichlet boundary conditions, and $\sigma(\nabla u)$ denotes the usual (linear) Lamé-Navier stress tensor.

As it is well known that the effort for the optimization is directly linked to the number of unknowns present in the discretization we will derive an a posteriori error estimator in order to drive local mesh refinement with respect to a given target quantity.

Finally we will give an outlook to possible extensions.

Ronald Hoppe, University of Augsburg (with F. Ibrahim, M. Hintermüller, M. Hinze, Y. Iliash)

Adaptive space-time finite element approximations of parabolic optimal control problems

We consider adaptive space-time finite element approximations of parabolic optimal control problems with distributed controls based on an approach where the optimality system is stated as a fourth order elliptic boundary value problem. The numerical solution relies on the formulation of the fourth order equation as a system of two second order ones which enables the discretization by P1 conforming finite elements with respect to simplicial triangulations of the space-time domain. The resulting algebraic saddle point problem is solved by preconditioned Richardson iterations featuring preconditioners constructed by means of appropriately chosen left and right transforms. The space-time adaptivity is realized by a reliable residual-type a posteriori error estimator which is derived by the evaluation of the two residuals associated with the underlying second order system. Numerical results are given that illustrate the performance of the adaptive space-time finite element approximation.

Robust optimization

Tue.1.MA 004

Dynamic optimization and its applications

Organizer/Chair Vineet Goyal, Columbia University · Invited Session

Dan Iancu, Stanford University (with Mayank Sharma, Maxim Sviridenko)

Supermodularity and dynamic robust optimization

We consider two classical paradigms for solving Dynamic Robust Optimization (DRO) problems: (1) Dynamic Programming (DP), and (2) policies parameterized in model uncertainties (i.e., decision rules), obtained by solving tractable convex optimization problems. We provide a set of unifying conditions (based on the interplay between the convexity and supermodularity of the DP value functions, and the lattice structure of the uncertainty sets) that guarantee the optimality of the class of *affine* decision rules. We also derive conditions under which such rules can be recovered by optimizing simple (e.g., affine) functions over the uncertainty sets. Our results suggest new modeling paradigms for robust optimization, and our proofs, bringing together ideas from three areas of optimization typically studied separately (robust, combinatorial – lattice programming and supermodularity, and global – the theory of concave envelopes), may be of independent interest. We exemplify our results in an application concerning the design of flexible contracts in a two-echelon supply chain, where all optimal contractual pre-commitments and optimal ordering policies can be found by solving a small LP.

Omid Nohadani, Purdue University

Robust evolution-based optimization in radiation therapy

The treatment of solid cancer tumors with external radiation is typically planned based on information that is collected during the initial examination. The overall goal of the treatment is to eliminate the tumor, hence a certain evolution is anticipated. However, current optimized radiation delivery strategies do not vary over the course of the treatment,

which typically spans over four to six weeks. We present novel methods that address this issue by taking the changes in the tumor into account and exploiting its evolution to both enhance the recovery and increase the success of the therapy. We demonstrate the performance of the method based on clinical cases, where a) the geometric shape of the tumor varies or b) the cell sensitivity to radiation and its effect changes over time. Moreover, the presented treatment plans are intrinsically robust to deviations from the assumed evolution path.

Vineet Goyal, Columbia University (with Dimitris Bertsimas)

Static vs. dynamic robust optimization

Most real world problems require optimization models that handle uncertain parameters. In a dynamic robust optimization framework, uncertainty is modeled as a set and we optimize over the worst-case realization of the uncertain parameters. We can compute an optimal fully-adjustable solution via a classical DP approach but this is often intractable. Another solution paradigm is to construct a static solution that is feasible for all future uncertainty realizations. This is a tractable approach but is often perceived to be highly conservative. We compare the performance of static solutions with optimal fully adjustable solutions and show that it is a good approximation for the dynamic robust optimization problem under fairly general conditions. In particular, we consider problems with linear constraints and linear objective under uncertainty and relate the performance of static solutions with the properties of uncertainty set. Our analysis also provides important insights about constructing good uncertainty sets in dynamic robust optimization problems.

Sparse optimization & compressed sensing

Tue.1.H 1028

Machine learning algorithms and implementations

Organizer/Chair Mark Schmidt, École normale supérieure · Invited Session

Mark Schmidt, École normale supérieure (with Francis Bach, Michael Frielander, Nicolas Le Roux)

Linearly-convergent stochastic gradient methods

This talk considers optimizing the sum of a large number of smooth functions, where the sum is strongly convex. Stochastic gradient algorithms only compute a single term in the sum on each iteration, leading to inexpensive iterations but unfortunately yielding sublinear convergence rates. In contrast, full-gradient methods achieve linear convergence rates at the expense of evaluating all terms on each iteration. We explore two strategies that exhibit the benefits of both approaches. First, we show that a linear convergence rate can be achieved at the expense of evaluating an increasing number of functions on each iteration. Second and more surprisingly, we propose a new method that only needs to evaluate a single term in the sum on each iteration but that still achieves a linear convergence rate. Numerical experiments indicate that the new algorithms can dramatically outperform standard methods.

Sewoong Oh, MIT (with Shah Devavrat, Negahban Sahand)

Statistical analysis of ranking from pairwise comparisons

The problem of ranking a collection of objects on the basis of a number of pairwise comparisons occurs naturally in many applications, including ranking players of a two-person game based on their records against each other. In this talk, we study two approaches of assigning scores which provide natural ordering of the objects. When the comparisons data is generated from the logit model, we provide performance guarantees for both approaches. First, we provide an upper bound on the error rate of the logistic regression applied to pairwise comparisons data. Next, we introduce an alternative approach of computing the scores of the objects from a stationary distribution of a random walk on a comparisons graph. We define the comparisons graph as a directed and weighted graph of objects where two objects are connected if the pair has been compared at least once, and the directed edges are weighted according to the outcome of the comparisons. Under the logit model, we provide an upper bound on the resulting error.

Stochastic optimization

Tue.1.MA 141

Methods of risk-averse optimization

Organizer/Chair Andrzej Ruszczyński, Rutgers University · Invited Session

Csaba Fabian, Kecskemet College

Computational aspects of risk-averse optimization

We deal with solution methods for two-stage stochastic linear programming problems, with an emphasis on variants that include convex risk measures. We consider cutting-plane and bundle-type methods.

The aim is to specialize general linear programming computing techniques to these stochastic problems; and on the other hand, to work out LP computational techniques based on ideas originally developed for the handling of risk measures.

Andrzej Ruszczyński, Rutgers University (with Ozlem Cavus)

Methods for solving risk-averse dynamic optimization problems

For risk-averse dynamic optimization problems with Markov risk measures, we present several computational methods for finding optimal policies. In particular, we extend to the risk-averse case the value iteration, policy iteration, and mathematical programming approaches. We illustrate the results on several applied problems.

Darinka Dentcheva, Stevens Institute of Technology (with Gabriela Martinez, Eli Wolfhagen)

Decomposition methods for solving two-stage optimization problems with stochastic ordering constraints

We consider two-stage risk-averse stochastic optimization problems with a stochastic ordering constraint on the recourse function. We consider the usual stochastic order, the increasing convex order, and the multivariate stochastic dominance. We propose decomposition methods to solve the problems and prove their convergence. Additionally, new characterizations of the increasing convex order relation are provided. Our methods exploit the decomposition structure of the risk-neutral two-stage problems and construct successive approximations of the stochastic ordering constraints. Numerical results confirm the efficiency of the methods.

Stochastic optimization

Tue.1.MA 144

Recent advances in risk representation

Organizer/Chair Erick Delage, HEC Montréal · Invited Session

Erick Delage, HEC Montréal (with Benjamin Armbruster)

Decision making under uncertainty when preference information is incomplete

We consider the problem of optimal decision making under uncertainty but assume that the decision maker's utility function is not completely known. Instead, we consider all the utilities that meet some criteria, such as preferring certain lotteries over certain other lotteries and being risk averse, s -shaped, or prudent. This extends the notion of stochastic dominance. We then give tractable formulations for such decision making problems. We formulate them as robust utility maximization problems, as optimization problems with stochastic dominance constraints, and as robust certainty equivalent maximization problems. We use a portfolio allocation problem to illustrate our results.

Dessislava Pachamanova, Babson College (with Cheekiat Low, Melvyn Sim)

Skewness-aware asset allocation: A new theoretical framework and empirical evidence

This paper presents a new measure of skewness, skewness-aware deviation, that can be linked to prospective satisficing risk measures and tail risk measures such as Value-at-Risk. We show that this measure of skewness arises naturally also when one thinks of maximizing the certainty equivalent for an investor with a negative exponential utility function, thus bringing together the mean-risk, expected utility, and prospective satisficing measures frameworks for an important class of investor preferences. We generalize the idea of variance and covariance in the new skewness-aware asset pricing and allocation framework. We show via computational experiments that the proposed approach results in improved and intuitively appealing asset allocation when returns follow real-world or simulated skewed distributions. We also suggest a skewness-aware equivalent of the classical capital asset pricing model beta, and study its consistency with the observed behavior of the stocks traded at the NYSE between 1963 and 2006.

Chen Chen, Columbia University (with Garud Iyengar, Ciamac Moallemi)

An axiomatic approach to systemic risk

Systemic risk is an issue of great concern in modern financial markets as well as, more broadly, in the management of complex systems. We propose an axiomatic framework for systemic risk. Our framework allows for an independent specification of (1) a functional of the cross-sectional profile of outcomes across agents in the system in a single scenario of nature, and (2) a functional of the profile of aggregated outcomes across scenarios of nature. This general class of systemic risk measures captures many specific measures of systemic risk that have recently been proposed as special cases, and highlights their implicit assumptions. Moreover, the systemic risk measures that satisfy our conditions yield decentralized decompositions, i.e., the systemic risk can be decomposed into risk due to individual agents. Furthermore, one can associate a shadow price for systemic risk to each agent that cor-

rectly accounts for the externalities of the agent's individual decision-making on the entire economy

Stochastic optimization

Tue.1.MA 376

Multistage stochastic mixed 0-1 optimization: Algorithms and applications

Organizer/Chair Laureano Escudero, Universidad Rey Juan Carlos · Invited Session

Aitziber Unzueta, University of the Basque Country (with Unzueta Aitziber, Gloria Perez, Laureano Escudero, Garín María Araceli)

Scenario cluster Lagrangian decomposition

We introduce four scenario cluster based Lagrangian decomposition (CLD) procedures for obtaining strong lower bounds to the (optimal) solution value of two-stage stochastic mixed 0–1 problems. At each iteration of the Lagrangian based procedures, the traditional aim consists of obtaining the solution value of the corresponding Lagrangian dual via solving scenario submodels once the nonanticipativity constraints have been dualized. Instead of considering a splitting variable representation over the set of scenarios, we propose to decompose the model into a set of scenario clusters. We compare the computational performance of the subgradient method, the volume algorithm, the progressive hedging algorithm and the dynamic constrained cutting plane scheme for different numbers of scenario clusters. Our computational experience shows that the CLD procedures outperform the traditional LD scheme for single scenarios both in the quality of the bounds and computational effort. Additionally, our CLD approach obtains very frequently the optimal solution of the problem outperforming the plain use of a state-of-the-art MIP solver. An extensive computational experience is reported.

Laureano Escudero, Universidad Rey Juan Carlos (with Juan Monge, Dolores Romero-Morales)

Stochastic tactical supply chain management under uncertainty

The uncertainty in the supply tactical chain management (STSM) is due to the stochasticity inherent in some parameters for dynamic (multiperiod) planning problems, mainly, product demand and demand loss, production cost and resources availability, and it is treated via scenario analysis. We present a modeling framework for solving the multiperiod stochastic mixed 0–1 STSM problem. A scenario tree based scheme is used to represent the parameters' uncertainty and for designing the deterministic equivalent model (DEM) for risk management by implementing the risk averse strategies based on scenario immunization, average conditional value-at-risk and stochastic dominance constraints. Solving the huge DEM instances is not affordable by using plain MIP solvers. Instead of that, we present an extension of a stochastic dynamic programming metaheuristic, by including the handling of constraints linking variables from different scenarios and constraints that do have variables that do not belong to any specific scenario. Some computational experience is reported.

María Garín, University of the Basque Country, UPV/EHU (with Laureano Escudero, María Merino, Gloria Pérez)

A BFC-MS algorithm for solving multistage mixed 0–1 stochastic problems with risk averse stochastic dominance constraints

In the context of stochastic optimization, the multistage mixed 0–1 deterministic equivalent models (DEM) use to be very large and difficult to solve. So, the plain use of even MIP state-of-the-art solvers for optimizing the related DEM requires an unaffordable computing effort or simply cannot be solved. The alternative is to use decomposition methods of the full model in smaller MIP submodels. Moreover, the general approach (so named risk neutral) has the inconvenience of providing a solution that ignores the variance of the objective value of the scenarios, and so, the occurrence of scenarios with an objective value below the expected one. In this work we present the optimization of the objective function expected value subject to stochastic dominance constraints for a set of profiles. The price to pay is that the DEM becomes much bigger, augmented by new variables and constraints. So, we present an extension of our BFC that consider nonsymmetric scenario trees, where a special treatment is given to the constraints that link variables from different scenarios.

Telecommunications & networks

Tue.1.H 3002

Flow and path problems

Chair Clemens Thielen, University of Kaiserslautern

Clemens Thielen, University of Kaiserslautern (with Stephan Westphal)

Maximum flows with minimum quantities

We consider a variant of the maximum flow problem where the flow on each arc in the network is restricted to be either zero or above a

given lower bound (a *minimum quantity*). This problem has recently been shown to be weakly NP-complete even on series-parallel graphs.

We show that it is strongly NP-hard to approximate the maximum flow problem with minimum quantities (MFPMQ) on general graphs within any positive factor. On series-parallel graphs, however, we present a pseudo-polynomial dynamic programming algorithm for the problem. Moreover, we show that the problem is still weakly NP-complete on general graphs for the case that the minimum quantity is the same for each arc in the network and we present a $(2 - \frac{1}{\lambda})$ -approximation algorithm for this case, where λ denotes the common minimum quantity of all arcs.

Marco Senatore, University of Rome "Tor Vergata" (with David Adjiashvili)

The online replacement path problem

We study a natural online variant of the replacement path problem. The replacement path problem asks to find for a given graph $G = (V, E)$, two designated vertices $s, t \in V$ and a shortest s - t path P in G , a replacement path P_e for every edge e on P . We adapt this problem to deal with the natural scenario that the identity of the failed edge only becomes available when the routing mechanism tries to cross the edge. This situation is motivated by applications in distributed networks, where information about recent changes in the network is only stored locally, and fault-tolerant optimization, where an adversary tries to delay the discovery of the materialized scenario as much as possible. Consequently, we define the online replacement path problem, which asks to find a nominal s - t path Q and detours Q_e for every edge on Q , such that the worst-case arrival time at the destination is minimized. Our main contribution is a label setting algorithm solving the problem in undirected graphs in time $O(m \log n)$ and linear space for all sources and a single destination. We also present algorithms for extensions of the model to any bounded number of failed edges.

Joao Paulo Araujo, Pontificia Universidade Catolica (PUC-RIO) (with Pascal Berthomé, Madiagne Diallo, Fernanda Raupp)

An algorithm for the multi-terminal maximum flow

In the context of network flows, the multi-terminal maximum flow problem is an extension of the well known single source-single terminal maximum flow problem. In the multi-terminal case, the maximum flow is calculated between all pairs of nodes. Clearly, considering a symmetric network with n nodes, this problem can be solved by applying a maximum flow algorithm $n(n-1)/2$ times, whereas the traditional methods can solve it with only $n-1$ applications. This work seeks to elaborate an algorithm able to solve the multi-terminal maximum flow problem with a computational complexity lower than the existing methods. The recent theory of sensitivity analysis, which studies the influence of an edge capacity variation on the multi-terminals maxima flows, is employed on the development of the algorithm. Techniques of the traditional methods, such as the contraction of nodes, are also part of the proposed method. Finally, the algorithm is computationally tested with all combined feature variations and heuristics. For a given instance, the algorithm showed efficiency very close to the traditional methods.

Variational analysis

Tue.1.H 2035

Nonsmooth analysis via piecewise-linearization

Organizer/Chair Andreas Griewank, Humboldt University · Invited Session

Kamil Khan, Massachusetts Institute of Technology (with Paul Barton)

Evaluating an element of the Clarke generalized Jacobian of a piecewise differentiable function

The [Clarke] generalized Jacobian of a locally Lipschitz continuous function is a derivative-like set-valued mapping that contains slope information. Bundle methods for nonsmooth optimization and semismooth Newton methods for equation solving require evaluation of generalized Jacobian elements. However, since the generalized Jacobian does not satisfy calculus rules sharply, this evaluation can be difficult.

In this work, a method is presented for evaluating generalized Jacobian elements of a nonsmooth function that is expressed as a finite composition of absolute value functions and continuously differentiable functions. The method makes use of the principles of automatic differentiation and the theory of piecewise differentiable functions, and is guaranteed to be computationally tractable relative to the cost of a function evaluation. The presented techniques are applied to nonsmooth example problems for illustration.

Andreas Griewank, Humboldt University

On piecewise linearization and lexicographic differentiation

It is shown how functions that are defined by an evaluation programs can be approximated locally by a piecewise-linear model. In contrast to the standard approach in algorithmic or automatic differentiation, we allow for the occurrence of nonsmooth but Lipschitz continuous elemental functions like the absolute value function $\text{abs}()$, $\text{min}()$, $\text{max}()$,

and more general table look ups. Then the resulting composite function is *piecewise differentiable* in that it is everywhere the continuous selection of a finite number of smooth functions [Scholtes]. Moreover, it can be locally approximated by a piecewise-linear model with a finite number of kinks between open polyhedra decomposing the function domain. The model can easily be generated by a minor modification of the ADOL-C and other standard AD tools.

The discrepancy between the original function and the model is of second order in the distance from the development point. Consequently, successive piecewise linearization yields bundle type methods for unconstrained minimization and Newton type equation solvers, for which we establish local convergence under standard assumptions.

Sabrina Fiege, Universität Paderborn (with Andreas Griewank, Andrea Walther)

An exploratory line-search for piecewise smooth functions

Many scalar or vector functions occurring in numerical applications are not continuously differentiable. This situation arises in particular through the use of l_1 or l_∞ penalty terms or the occurrence of $\text{abs}()$, $\text{min}()$ and $\text{max}()$ in the problem function evaluations themselves. If no other nonsmooth elemental functions are present, generalized gradients and Jacobians of these piecewise smooth functions can now be computed in an AD like fashion by *lexicographic differentiation* as introduced by Barton & Kahn, Griewank and Nesterov. However, at almost all points these generalized derivatives reduce to classical derivatives, so that the effort to provide procedures that can calculate generalized Jacobians nearly never pay off. At the same time the Taylor approximations based on these classical derivative singeltons may have a miniscule range of validity. Therefore, one alternative goal is to compute the critical step multiplier along a given search direction that leads to either the nearest kink. The achievement of this goal can not be guaranteed absolutely, but we verify necessary conditions. We will present numerical results verifying the theoretical results.

Variational analysis

Tue.1.H 2051

Variational inequalities and optimization problems on Riemannian manifolds

Organizers/Chairs Genaro López, University of Seville; Chong Li, Zhejiang University · Invited Session

Vittorio Colao, Università della Calabria

Equilibrium problems in Hadamard manifolds

Equilibrium problems in linear spaces had been widely investigated in recent years and by several authors. It had been proved that a broad class of problems, such as variational inequality, convex minimization, fixed point and Nash equilibrium problems can be formulated as equilibrium problems.

In this talk, I will deal with equilibrium problems in the setting of manifolds with nonpositive sectional curvature. An existence result will be presented, together with applications to variational inequality, fixed point for multivalued maps and Nash equilibrium problems. I will also introduce a firmly nonexpansive resolvent and discuss an approximation result for equilibrium points.

Laurentiu Leustean, Simion Stoilow Institute of Mathematics of the Romanian Academy (with David Ariza-Ruiz, Genaro Lopez-Acedo)

Firmly nonexpansive mappings in classes of geodesic spaces

Firmly nonexpansive mappings play an important role in metric fixed point theory and optimization due to their correspondence with maximal monotone operators. In this paper we do a thorough study of fixed point theory and the asymptotic behaviour of Picard iterates of these mappings in different classes of geodesic spaces, as (uniformly convex) W -hyperbolic spaces, Busemann spaces and CAT(0) spaces. Furthermore, we apply methods of proof mining to obtain effective rates of asymptotic regularity for the Picard iterations.

Paulo Oliveira, Federal University of Rio de Janeiro (with Glaydston Bento, João Cruz Neto, Erik Quiroz)

Proximal and descent methods on Riemannian manifolds

This talk has two parts. In the first, it is analyzed the proximal point method applied in Hadamard manifolds, associated to the corresponding distance. The considered functions are locally Lipschitz quasiconvex. Under reasonable hypothesis, it is proved the global convergence of the sequence generated by the method to a critical point. In the second part, the concerned class are lower semicontinuous functions satisfying Kurdyka-Lojasiewicz property. An abstract convergence analysis for inexact methods in Riemannian manifolds allows to obtain full convergence of bounded sequences applied to proximal method, associated to a quasi-distance (the usual distance without symmetry). The results are independent of the curvature of the manifold. A second application of the abstract theory is the convergence of inexact descent method for that class of functions on Hadamard manifolds. This extends known results for Riemannian manifolds with positive curvature. Finally, some applications are cited in related papers.

Approximation & online algorithms

Tue.2.H 3010

Travelling salesman problem I

Organizers/Chairs Sylvia Boyd, University of Ottawa; David Shmoys, Cornell University · Invited Session

Sylvia Boyd, University of Ottawa (with René Sitters, Leen Stougie, Suzanne van der Ster)

The travelling salesman problem on cubic and subcubic graphs

We study the travelling salesman problem (TSP) on the metric completion of cubic and subcubic graphs, which is known to be NP-hard. The problem is of interest because of its relation to the famous $\frac{4}{3}$ conjecture for metric TSP, which says that the integrality gap, i.e., the worst case ratio between the optimal values of the TSP and its linear programming relaxation (the subtour elimination relaxation), is $\frac{4}{3}$. We present the first algorithm for cubic graphs with approximation ratio $\frac{4}{3}$. The proof uses polyhedral techniques in a surprising way, which is of independent interest. In fact we prove constructively that for any cubic graph on n vertices a tour of length $\frac{4n}{3} - 2$ exists, which also implies the $\frac{4}{3}$ conjecture, as an upper bound, for this class of graph-TSP.

Anke van Zuylen, Max Planck Institute for Informatics (with Frans Schalekamp, David Williamson)

A proof of the Boyd-Carr conjecture

Determining the precise integrality gap for the subtour LP relaxation of the traveling salesman problem is a significant open question, with little progress made in thirty years in the general case of symmetric costs that obey triangle inequality. Boyd and Carr observe that we do not even know the worst-case upper bound on the ratio of the optimal 2-matching to the subtour LP; they conjecture the ratio is at most $\frac{10}{9}$.

In this paper, we prove the Boyd-Carr conjecture. In the case that a fractional 2-matching has no cut edge, we can further prove that an optimal 2-matching is at most $\frac{10}{9}$ times the cost of the fractional 2-matching.

András Sebő, CNRS, Grenoble-INP, UJF (with Jens Vygen)

Shorter tours by nicer ears

I will sketch some ideas leading us to a $7/5$ -approximation algorithm for the graphic TSP, a $3/2$ -approximation algorithm for the minimum connected T -join problem containing the graphic $s - t$ -path TSP and a $4/3$ -approximation algorithm for the smallest 2-edge-connected spanning subgraph problem. The key ingredients are:

- a special kind of ear-decomposition using matching theory (theorems of Lovász and Frank).
- optimization of the used ear-decomposition using matroid intersection.
- minmax theorems of these subjects transformed to linear programming weak duality.

The last make possible to deduce lower bounds for the graphic TSP. These are necessary for proving the approximation ratio and the integrality gap of some associated linear programs.

Approximation & online algorithms

Tue.2.MA 041

Practical implementations and models using approximation algorithms

Organizer/Chair David Phillips, U.S. Naval Academy · Invited Session

Rodrigo Carrasco, Columbia University (with Garud Iyengar, Cliff Stein)

Experimental results of approximation algorithms for energy aware scheduling

The increasing awareness of the environmental impact of massive data centres has led to an increased interest in energy management algorithms. We have developed several new constant factor approximation algorithms for energy aware scheduling problems. The objective is to minimize the sum of the total energy consumed and the total weighted completion time or the total weighted tardiness in the one machine non-preemptive setting, allowing for arbitrary precedence constraints and also release dates for the weighted completion time. Unlike previous known algorithms our new algorithms can handle general job-dependent energy cost functions extending their application to settings that have maintenance costs, wear and tear, replacement costs, etc., which in general also depend on the particular job being processed. In this work we seek to understand the practical performance of these algorithms. We show that the practical performance is significantly superior to the theoretical bounds and in fact are very close to optimal. Additionally, we present heuristic improvements and we also investigate their performance in other settings: online, total weighted flow time, multiple machines, etc.

Eyjolfur Asgeirsson, Reykjavik University (with Pradipta Mitra)

Performance of distributed game theoretic algorithms for single slot scheduling in wireless networks

We consider the capacity problem in wireless networks where the

goal is to maximize the number of successful connections in arbitrary wireless networks where a transmission is successful only if the signal-to-interference-plus-noise ratio at the receiver is greater than some threshold. We study a game theoretic approach towards capacity maximization introduced by Andrews and Dinitz, where the key to the approximation is the use of low-regret algorithms. We prove vastly improved bounds for the game theoretic algorithm. In doing so, we achieve the first distributed constant factor approximation algorithm for capacity maximization for the uniform power assignment. When compared to the optimum where links may use an arbitrary power assignment, we prove a $O(\log \Delta)$ approximation, where Δ is the ratio between the largest and the smallest link in the network. This is an exponential improvement of the approximation factor compared to existing results for distributed algorithms. All our results work for links located in any metric space. In addition, we provide simulation studies clarifying the picture on distributed algorithms for capacity maximization.

David Phillips, U.S. Naval Academy (with Adam Carpenter, Lawrence Leemis, Alan Papir, Grace Phillips)

Scheduling and planning magnetic resonance imaging machines

We devise models and algorithms to estimate the impact of current and future patient demand for examinations on magnetic resonance imaging (MRI) machines at a hospital radiology department. Our work helps improve scheduling decisions and supports MRI machine personnel and equipment planning decisions. Of particular novelty is our use of approximation algorithms from scheduling to compute the competing objectives of maximizing examination throughput and patient-magnet utilization. We also use resource augmentation to show that our algorithm is a $O(1)$ -speed algorithm for computing a bicriteria solution. We present computational results demonstrating how our model can be used to both assess scheduling decisions as well as help guide planning decisions.

Combinatorial optimization

Tue.2.H 3004

Cone factorizations and lifts of convex sets

Organizers/Chairs Pablo Parrilo, Massachusetts Institute of Technology; Rekha Thomas, University of Washington · Invited Session

Stephen Vavasis, University of Waterloo (with Venkat Chandrasekaran, Xuan Vinh Doan)

Identifying k large submatrices using convex programming

We consider the problem of identifying k large approximately rank-one submatrices of a nonnegative data matrix. Stated in a certain manner, this problem is NP-hard, but has important applications in data mining. In particular it is a version of the well-known nonnegative matrix factorization, which has been applied to document classification, image decomposition, and analysis of biochemical experiments. We prove that if the data is constructed according to a certain randomized model, then the k blocks can be recovered in polynomial time via convex relaxation.

João Gouveia, University of Coimbra (with Richard Robinson, Rekha Thomas)

Semidefinite lifts of polytopes

Recently, there has been a renewed interest in understanding the existence of small linear or semidefinite representations for polytopes. These representations, which are obtained by adding extra variables, are deeply connected to certain special factorizations of the slack matrix of the polytopes.

In this talk, we explore this connection to present some results on the size of semidefinite lifts of polytopes, with focus on examples, surveying what is known in the area.

Francois Glineur, UCL / CORE

Compact polyhedral approximations for convex sets defined by polynomials

Ben-Tal and Nemirovski proposed in 2001 a way to approximate second-order cone optimization with linear optimization. Their technique relies on a clever linear extended formulation for the two-dimensional regular 2^k -gon. Since these polygons approximate the two-dimensional disc, polyhedral approximations for any second-order cone optimization problem can be derived. These approximations are compact in the sense that they feature a number of vertices that is exponential in the size of their extended formulation.

In this talk, we present a generalization of this construction that provides new polyhedral approximations for a large class of convex sets defined by convex univariate polynomial inequalities. It relies on a compact extended formulation for a polyhedral approximation of a specific spectrahedron, namely the convex hull of the moment curve. This construction features links with cyclic polytopes and the trigonometric moment curve. We also report on numerical experiments demonstrating usefulness of this technique.

Combinatorial optimization

Tue.2.H 3005

Lift-and-project methods for combinatorial optimization problems

Organizer/Chair Konstantinos Georgiou, University of Waterloo · Invited Session

Eden Chlamtac, Tel Aviv University

Reduced integrality gaps and improved approximations via lift-and-project methods

We consider natural convex relaxations of integer programs, such as linear programs (LP) and semi-definite programs (SDP), and examine how well they approximate various problems in combinatorial optimization. The “integrality gap” – the worst-case gap between the optimum of a convex relaxation and that of the integer program it approximates – can sometimes be reduced by considering a hierarchy of relaxations derived from lift-and-project methods.

We will look at different hierarchies, and some universal properties of the LP and SDP relaxations derived from them. Moreover, we will see how, for certain NP-hard optimization problems, we can achieve improved approximations using such strengthened relaxations while maintaining polynomial running time overall.

Monique Laurent, CWI, Amsterdam and U Tilburg (with Etienne de Klerk)

Error bounds for sums of squares relaxations of some polynomial optimization problems

We consider semidefinite programming relaxations for polynomial optimization problems based on sums of squares of polynomials and the dual relaxations based on moment matrices.

In particular, we discuss error bounds for optimization over the hypercube for the hierarchy of relaxations corresponding to the Positivstellensätze of Handelman and of Schmüdgen. These bounds are explicit and sharpen an earlier result of Schweighofer (2004). We also discuss links to error bounds for optimization over the simplex and for the Lasserre hierarchy.

Madhur Tulsiani, Toyota Technological Institute at Chicago

Effectiveness and limitations of local constraints

I will give an overview of various hierarchies which strengthen linear and semidefinite programs by adding increasingly larger local constraints. I will discuss some recent techniques for arguing about the quality of approximation achieved by these hierarchies. The focus of the talk will be on lower bounds and connections to other areas like proof complexity.

Combinatorial optimization

Tue.2.H 3008

Combinatorics and geometry of linear optimization I

Organizers/Chairs Antoine Deza, McMaster University; Jesus De Loera, University of California, Davis · Invited Session

Francisco Santos, Universidad De Cantabria

Counter-examples to the Hirsch conjecture

About two years ago I announced the first counter-example to the (bounded) Hirsch conjecture: a 43-dimensional polytope with 86 facets and diameter (at least) 44. It was based on the construction of a 5-prismatoid of “width” 6, with 48 vertices. Since then, some improvements or related results have been obtained: S.-Stephen-Thomas showed that prismatoids of dimension 4 cannot lead to non-Hirsch polytopes, and S.-Matschke-Weibel constructed smaller 5-prismatoids of length 6, now with only 25 facets. These produce counter-examples to the Hirsch conjecture in dimension 20.

But, all in all, the main problem underlying the Hirsch Conjecture remains as open as before. In particular, it would be very interesting to know the answer to any of the following questions:

- Is there a polynomial bound $f(n)$ for the diameter of n -faceted polytopes? (“Polynomial Hirsch Conjecture”).
- Is there a linear bound? Is $f(n) = 2n$ such a bound?

A conjecture of Hänle, suggested by the work of Eisenbrand et al. in the abstract setting of “connected layer sequences” would imply that nd is an upper bound.

Nicolai Hähnle, TU Berlin

An abstract view on the polynomial Hirsch conjecture

The question of whether a strongly polynomial algorithm for linear programming exists is one of the great mysteries of the field. It has motivated the polynomial Hirsch conjecture, which claims that the diameter of the vertex-edge graph of every polyhedron is bounded by a polynomial in its affine dimension and the number of facets.

The best known upper-bound on the diameter of polyhedra is a quasi-polynomial bound due to Kalai and Kleitman. What properties of polyhedra make this upper bound work? What techniques could be useful in improving it? We present a purely combinatorial abstraction of the

graph of a polyhedron as a way of understanding these questions better. In particular, we present an abstraction in which an almost quadratic construction is known, while the Kalai-Kleitman bound still holds with essentially the same proof.

We made the conjecture that an upper bound of $d(n - 1)$ holds for this abstraction. We present some evidence for and against this conjecture, and discuss open questions that could guide possible approaches to the polynomial Hirsch conjecture.

Yuriy Zinchenko, University of Calgary (with Antoine Ddeza, Tamas Terlaky)

Polytopes and arrangements: Diameter and curvature

We introduce a continuous analogue of the Hirsch conjecture and a discrete analogue of the result of Dedieu, Malajovich and Shub. We prove a continuous analogue of the result of Holt and Klee, namely, we construct a family of polytopes which attain the conjectured order of the largest total curvature, and a continuous analogue of a d -step equivalence result for the diameter of a polytope. Potential extensions of this work will be highlighted.

Combinatorial optimization

Tue.2.H 3012

Algorithms for transistor-level layout

Organizer/Chair Stefan Hougardy, University of Bonn · Invited Session

Tim Nieberg, University of Bonn (with Stefan Hougardy, Jan Schneider)

BonnCell: Routing of leaf cells in VLSI design

In this talk, we present and discuss the routing engine of BonnCell. Given a placed leaf cell, the task at hand is to find an embedding of rectilinear Steiner trees which realizes a given netlist subject to various design rules. As a leaf cell is rather small compared to other structures usually present in VLSI design, all constraints have to be considered at the same time and as accurately as possible making leaf cell routing a very complicated problem in practice. The underlying algorithm of our solution uses a constraint generation approach based on a MIP model for packing Steiner trees in graphs and is extended to produce a problem specific formulation. While relaxing (some of) the constraints is not an option for the application, there are several ways to improve on the solution times. These include further strong valid inequalities and also some heuristic elements. Next to these, we also report on results for current real-world designs at the 22 nm chip production node.

Jan Schneider, University of Bonn (with Stefan Hougardy, Tim Nieberg)

BonnCell: Placement of leaf cells in VLSI design

The automatic layout of leaf cells in VLSI design requires significantly different algorithms than classical tools for the physical design of VLSI instances. While the number of placement objects in leaf cells is very small, at most a few dozen, the placement constraints are not covered by usual approaches. We present the placement engine of our tool BonnCell, which computes optimal placements for most real-world instances within seconds. Optimality is measured with respect to a target function that models the cell routability and proved to be very accurate in practice.

Stefan Hougardy, University of Bonn

Transistor level layout: Algorithms and complexity

In hierarchical VLSI design a leaf cell is a functional unit at the lowest level of the hierarchy. A leaf cell implements a specific function. It is built from a small number of transistors that are connected by wires.

The problem of automatically generating transistor level layouts of leaf cells has been studied for several decades. It requires the solution of hard problems as for example Steiner tree packing problems or linear arrangement problems. We give an overview of some of the algorithmic problems appearing in the transistor level layout of leaf cells and discuss why current VLSI technology requires new algorithms.

Combinatorial optimization

Tue.2.H 3013

Matching and related problems

Organizer/Chair Gyula Pap, Eötvös University · Invited Session

Krisztof Bérczi, Eger Research Group, Eötvös Loránd University, Budapest

Restricted b -matchings

A $C_{\leq k}$ -free 2-factor is a 2-factor not containing cycles of length at most k . Cornuéjols and Pulleyblank showed that deciding the existence of such a subgraph is NP-complete for $k \geq 5$. On the other hand, Hartvigsen proposed an algorithm for the triangle-free case ($k = 3$). The existence of a $C_{\leq 4}$ -free or C_4 -free 2-matching is still open (in the latter, triangles are allowed). Yet imposing the condition that the graph is subcubic (that is, the maximum degree of G is 3), these problems become solvable.

Considering the maximum weight version of the problems, there is a firm difference between triangle- and square-free 2-factors. Király showed that finding a maximum weight square-free 2-factor is NP-complete even in bipartite graphs with $0 - 1$ weights. On the other hand, for subcubic graphs, polynomial-time algorithms were given by Hartvigsen and Li, and recently by Kobayashi for the weighted C_3 -free 2-factor problem with an arbitrary weight function. The former result implies that we should not expect a nice polyhedral description of the square-free 2-factor polytope. However, the latter suggests that the triangle-free case may be solvable.

Kenjiro Takazawa, RIMS and G-SCOP (with Sylvia Boyd, Satoru Iwata)

Covering cuts in bridgeless cubic graphs

In this talk we are interested in algorithms for finding 2-factors that cover certain prescribed edge-cuts in bridgeless cubic graphs. We present an algorithm for finding a minimum-weight 2-factor covering all the 3-edge cuts in weighted bridgeless cubic graphs, together with a polyhedral description of such 2-factors and that of perfect matchings intersecting all the 3-edge cuts in exactly one edge. We further give an algorithm for finding a 2-factor covering all the 3- and 4-edge cuts in bridgeless cubic graphs. Both of these algorithms run in $O(n^3)$ time, where n is the number of vertices.

As an application of the latter algorithm, we design a 6/5-approximation algorithm for finding a minimum 2-edge-connected subgraph in 3-edge-connected cubic graphs, which improves upon the previous best ratio of 5/4. The algorithm begins with finding a 2-factor covering all 3- and 4-edge cuts, which is the bottleneck in terms of complexity, and thus it has running time $O(n^3)$. We then improve this time complexity to $O(n^2 \log^4 n)$ by relaxing the condition of the initial 2-factor and elaborating the subsequent processes.

David Hartvigsen, University of Notre Dame (with Yanjun Li)

A generalized k -matching problem

A simple k -matching in a graph is a subgraph all of whose nodes have degree at most k . The problem of finding a simple k -matching with a maximum number of edges is well studied and results include a max-min theorem and polynomial-time algorithm. A simple k -matching is called j -restricted if each connected component has more than j edges. In this talk we consider the problem of finding j -restricted simple k -matchings that have a maximum number of edges. We present a max-min theorem and polynomial-time algorithm when $j < k$. Previous work on this problem considers the special case $j < k = 2$.

Combinatorial optimization

Tue.2.H 3021

Sampling, sorting and graph traversal: Algorithms for finding permutations

Organizer/Chair Alantha Newman, DIMACS · Invited Session

Zhiyi Huang, University of Pennsylvania (with Sampath Kannan, Sanjeev Khanna)

Algorithms for the generalized sorting problem

We study the generalized sorting problem where we are given a set of n elements to be sorted but only a subset of all possible pairwise element comparisons is allowed. The goal is to determine the sorted order using the smallest possible number of allowed comparisons. The generalized sorting problem may be equivalently viewed as follows. Given an undirected graph $G = (V, E)$ where V is the set of elements to be sorted and E defines the set of allowed comparisons, adaptively find the smallest subset $E' \subseteq E$ of edges to probe so that the graph induced by E' contains a Hamiltonian path.

When G is a complete graph, it is the standard sorting problem. Another well-studied case is the nuts and bolts problem where the allowed comparison graph is a complete bipartite graph between two equal-size sets. For these cases, it is known there are deterministic sorting algorithms using $\Theta(n \log n)$ comparisons. However, when the allowed comparison graph is arbitrary, no bound better than the trivial $O(n^2)$ one was known. Our main result is a randomized algorithm that sorts any allowed comparison graph using $\tilde{O}(n^{3/2})$ comparisons with high probability.

Sarah Miracle, Georgia Institute of Technology (with Prateek Bhakta, Dana Randall, Amanda Streib)

Mixing times of self-organizing lists and biased permutations

Sampling permutations from S_n is a fundamental problem from probability theory. The nearest neighbor transposition chain is known to mix in time $\Theta(n^3 \log n)$ in the unbiased case and time $\Theta(n^2)$ in the constant bias case. It was conjectured that the chain is always rapidly mixing when the inversion probabilities are positively biased, i.e., we put nearest neighbor pair $x < y$ in order with bias $1/2 \leq p_{xy} \leq 1$ and out of order with bias $1 - p_{xy}$. We prove the chain is rapidly mixing for two classes: "Choose Your Weapon," where we are given r_1, \dots, r_{n-1} with $r_i \geq 1/2$ and $p_{x,y} = r_x$ for all $x < y$ (the dominant player chooses the

game, thus fixing their probability of winning), and "League hierarchies," where there are two leagues and players from the A-league have a fixed probability of beating players from the B-league, players within each league are divided into sub-leagues, and so forth recursively. Moreover, we also prove that the conjecture is false by exhibiting values for the p_{xy} , with $1/2 \leq p_{xy} \leq 1$ for all $x < y$, but for which the chain will require exponential time to converge.

Katarzyna Paluch, Institute of Computer Science, University of Wrocław (with Khaled Elbassioni, Anke van Zuylen)

Simpler approximation of the maximum asymmetric traveling salesman problem

We give a very simple approximation algorithm for the maximum asymmetric traveling salesman problem. The approximation guarantee of our algorithm is $2/3$, which matches the best known approximation guarantee by Kaplan, Lewenstein, Shafrir and Sviridenko. Our algorithm is simple to analyze, and contrary to previous approaches, which need an optimal solution to a linear program, our algorithm is combinatorial and only uses maximum weight perfect matching algorithm.

Complementarity & variational inequalities

Tue.2.MA 313

MPECs in function space I

Organizers/Chairs Michael Hintermüller, Humboldt-Universität zu Berlin; Christian Meyer, TU Dortmund · Invited Session

Daniel Wachsmuth, Universität Würzburg (with Karl Kunisch, Anton Schiela)

Convergence analysis of smoothing methods for optimal control of stationary variational inequalities

In the talk an optimal control problem subject to a stationary variational inequality is investigated. The optimal control problem is complemented with pointwise control constraints. The convergence of a smoothing scheme is analyzed. There, the variational inequality is replaced by a semilinear elliptic equation. It is shown that solutions of the regularized optimal control problem converge to solutions of the original one. Passing to the limit in the optimality system of the regularized problem allows to prove C-stationarity of local solutions of the original problem. Moreover, convergence rates with respect to the regularization parameter for the error in the control are obtained. These rates coincide with rates obtained by numerical experiments.

Thomas Surowiec, Humboldt University of Berlin (with Michael Hintermüller)

A PDE-constrained generalized Nash equilibrium problem with pointwise control and state constraints

We formulate a class of generalized Nash equilibrium problems (GNEP) in which the feasible sets of each player's game are partially governed by the solutions of a linear elliptic partial differential equation (PDE). In addition, the controls (strategies) of each player are assumed to be bounded pointwise almost everywhere and the state of the entire system (the solution of the PDE) must satisfy a unilateral lower bound pointwise almost everywhere. Under certain regularity assumptions (constraint qualifications), we prove the existence of a pure strategy Nash equilibrium. After deriving multiplier-based necessary and sufficient optimality conditions for an equilibrium, we develop a numerical method based on a non-linear Gauss-Seidel iteration, in which each respective player's game is solved via a nonsmooth Newton step. Convergence of stationary points is demonstrated and the theoretical results are illustrated by numerical experiments.

Carlos Rautenberg, Karl-Franzens-University of Graz (with Michael Hintermüller)

Hyperbolic quasi-variational inequalities with gradient-type constraints

The paper addresses a class of hyperbolic quasi-variational inequality (QVI) problems of first order and with constraints of the gradient-type. We study existence and approximation of solutions based on recent results of appropriate parabolic regularization, monotone operator theory and C_0 -semigroup methods. Numerical tests, where the subproblems are solved using semismooth Newton methods, with several nonlinear constraints are provided.

Conic programming

Tue.2.H 2036

Advances in convex optimization

Organizer/Chair Javier Peña, Carnegie Mellon University · Invited Session

Luis Zuluaga, Lehigh University (with Javier Peña, Juan Vera)

Positive polynomials on unbounded domains

Certificates of non-negativity are fundamental tools in optimization. A "certificate" is generally understood as an expression that makes the

Constraint programming

non-negativity of the function in question evident. Recently, sum-of-squares certificates of non-negativity for polynomials have been used to obtain powerful numerical techniques for solving polynomial optimization problems; in particular, for mixed integer programs, and non-convex binary programs. We present a new certificate of non-negativity for polynomials over the intersection of a closed set S and the zero set of a given polynomial $h(x)$. The certificate is written in terms of the set of non-negative polynomials over S and the ideal generated by $h(x)$. Our certificate of non-negativity yields a copositive programming reformulation for a very general class of polynomial optimization problems.

Martin Lotz, The University of Edinburgh (with Dennis Amelunxen)

Conditioning of the convex feasibility problem and sparse recovery

The problem of whether certain simple or sparse solutions to linear systems of equations can be found or approximated efficiently can often be cast in terms of a convex feasibility problem. In particular, condition numbers introduced for the complexity analysis of conic optimization problems play an important role in the analysis of such problems. We present results and geometric methods from the probabilistic analysis of condition numbers for optimization problems, and indicate how this analysis can be used to obtain sparse and simple recovery thresholds for problems with noise.

Javier Pena, Carnegie Mellon University (with Negar Soheili)

A smooth primal-dual perceptron-von Neumann algorithm

We propose an elementary algorithm for solving a system of linear inequalities $A^T y > 0$ or its alternative $Ax \geq 0, x \neq 0$. Our algorithm is a smooth version of the perceptron and von Neumann's algorithms. Our algorithm retains the simplicity of these algorithms but has a significantly improved convergence rate.

Conic programming

Tue.2.H 2038

Applications of semidefinite programming

Organizer/Chair Etienne de Klerk, Tilburg University · Invited Session

Amir Ali Ahmadi, MIT (with Raphaël Jungers, Pablo Parrilo, Mardavij Roozbehani)

Joint spectral radius, path-complete graphs, and semidefinite programming

The joint spectral radius (JSR) of a finite set of square matrices – a natural generalization of the notion of the spectral radius of a single matrix – characterizes the maximal growth rate that can be obtained by taking products, of arbitrary length, of all possible permutations of the matrices. Despite several undecidability and NP-hardness results related to computation (or approximation) of the JSR, the topic continues to attract attention because of a wide range of applications, including computation of the capacity of codes, robust stability of uncertain linear systems, Leontief input-output model of the economy with uncertain data, convergence of consensus algorithms, and many others. In this talk, we present our novel framework of *path-complete graph Lyapunov functions* which produces several hierarchies of asymptotically exact semidefinite programming relaxations with provable approximation guarantees. Our algorithms are based on new connections between ideas from control theory and the theory of finite automata.

Uwe Truetsch, Tilburg University (with Etienne de Klerk, Renata Sotirov)

A “smart” choice of a relaxation for the quadratic assignment problem within a branch-and-bound framework

The practical approach to calculate an exact solution for a quadratic assignment problem (QAP) via a branch-and-bound framework depends strongly on a “smart” choice of different strategies within the framework, for example the branching strategy, heuristics for the upper bound or relaxations for the lower bound. In this work, we compare different relaxations from the literature, in particular two promising semidefinite programming relaxations introduced by Zhao, Karisch, Rendl and Wolkowicz, and by Peng, Zhu, Luo and Toh respectively. The aim of our work is to generate and present a size-dependent choice of an appropriate relaxation that can be successfully used at a given node within a branch-and-bound framework.

Xuan Vinh Doan, University of Warwick (with Stephen Vavasis)

Feature extraction and data clustering with SDP-representable norms

We propose a convex optimization formulation with some SDP-representable norms to find approximately rank-one submatrices of a given nonnegative matrix. It has several applications in data mining, which includes feature extraction and data clustering. We develop a first-order method to solve the proposed optimization problem and report some promising numerical results.

Tue.2.H 3003A

CP hybrids for scheduling

Organizer/Chair Chris Beck, University of Toronto · Invited Session

Michele Lombardi, University of Bologna (with Andrea Bartolini, Luca Benini, Michela Milano)

Hybrid off-line/on-line workload scheduling via machine learning and constraint programming

Advances in combinatorial optimization in the last decades have enabled their successful application to an extensive number of industrial problems. Nevertheless, many real-world domains are still impervious to approaches such as constraint programming (CP), mathematical programming or metaheuristics. In many cases, the difficulties stem from troubles in formulating an accurate declarative model of the system to be optimized. This is typically the case for systems under the control of an on-line policy: even when the basic rules governing the controller are well known, capturing its behavior in a declarative model is often impossible by conventional means. Such a difficulty is at the root of the classical, sharp separation between off-line and on-line approaches.

In this work, we investigate a general method to combine off-line and on-line optimization, based on the integration of machine learning and combinatorial optimization technology. Specifically, we use an artificial neural network (ANN) to learn the behavior of a controlled system and plug it into a CP model by means of so-called neuron constraints.

Chris Beck, University of Toronto (with Ti Feng, Wen-Yang Ku, Jean-Paul Watson)

Loosely coupled hybrids: Tabu search, constraint programming and mixed integer programming for job shop scheduling

Since their introduction, metaheuristic algorithms have consistently represented the state of the art in solution techniques for the classical job-shop scheduling problem. This dominance is despite the availability of powerful search and inference techniques for scheduling problems developed by the constraint programming (CP) community and substantial increase in the power of commercial mixed integer programming (MIP) solvers. Building on observations of the performance characteristics of metaheuristic, CP, and MIP solvers, we investigate simple, loosely coupled hybrid algorithms for job-shop scheduling. Our hypothesis is that the fast, broad search capabilities of modern tabu search algorithms are able to very quickly converge on a set of very good, but likely sub-optimal, solutions. CP or MIP can then be seeded with these solutions to improve them and search for optimality proofs.

Thibaut Feydy, NICTA (with Andreas Schutt, Peter Stuckey)

Lazy clause generation for RCPSP

Lazy clause generation (LCG) is a recent generic method for solving constraint problems. LCG solvers integrate tightly finite domain propagation (FD) with the conflict analysis features of Boolean satisfiability (SAT) solvers. This technology is often order of magnitudes faster than traditional finite domain propagation on some hard combinatorial problems. In particular, we have used methods based on lazy clause generation to solve the resource constrained project scheduling problem (RCPSP) as well as the more general resource constrained project scheduling problem with generalized precedence relations (RCPSP-Max). These scheduling models have applications areas such as project management and production planning. Our experiments show the benefit of lazy clause generation for finding an optimal solution and proving its optimality in comparison to other state-of-the-art exact and non-exact methods. Our methods is able to find better solution faster on hard RCPSP and RCPSP-Max benchmarks. We were able to close many open problem instances and generates better solutions in most of the remaining instances.

Derivative-free & simulation-based opt.

Tue.2.H 3503

New techniques for optimization without derivatives

Organizers/Chairs Stefan Wild, Argonne National Laboratory; Luis Nunes Vicente, University of Coimbra · Invited Session

Margaret Wright, Courant Institute of Mathematical Sciences

Defining non-monotone derivative-free methods

Non-monotone strategies in optimization avoid imposing a monotonicity requirement at every iteration with the goal of achieving rapid convergence from an alternative strategy over a longer sequence of iterations. We consider how to define non-monotone derivative-free methods in, broadly, this same spirit, especially in light of recent worst-case complexity results that are closely tied to monotonicity requirements.

Getha Gray, Sandia National Labs (with Ethan Chan, John Guenther, Herbie Lee, John Sirola)

Calculating and using sensitivity information during derivative-free optimization routines

The incorporation of uncertainty quantification (UQ) into optimiza-

tion routines can help identify, characterize, reduce, and possibly eliminate uncertainty while drastically improving the usefulness of computational models and optimal solutions. Current approaches are in that they first identify optimal solutions and then, perform a series of UQ runs using these solutions. Although this approach can be effective, it can be computationally expensive or produce incomplete results. Model analysis that takes advantage of intermediate optimization iterates can reduce the expense, but the sampling done by the optimization algorithms is not ideal. In this talk, we discuss a simultaneous optimization and UQ approach that combines Bayesian statistical models and derivative-free optimization in order to monitor and use sensitivity information throughout the algorithm's execution.

Satyajith Amaran, Carnegie Mellon University (with Scott Bury, Nikolaos Sahinidis, Bikram Sharda)

A comparison of software and algorithms in unconstrained simulation optimization problems

Over the last few decades, several algorithms for simulation optimization (SO) have appeared and, along with them, diverse application areas for these algorithms. The algorithmic approaches proposed in the literature include ranking and selection, sample average approximation, metaheuristics, response surface methodology and random search. Application areas range from urban traffic control to investment portfolio optimization to operation scheduling. However, a systematic comparison of algorithmic approaches for simulation optimization problems from the literature is not available. At this juncture in the evolution of SO, it is instructive to review the size and kinds of problems handled as well as the performance of different classes of algorithms, both in terms of quality of solutions and number of experiments (or function evaluations) required. In this work, we use a library of diverse algorithms, and propose a method to assess their performance under homogeneous and heterogeneous variances on a recently-compiled simulation optimization test set. Discussions follow.

Finance & economics

Tue.2.H 3027

Financial optimization

Organizer/Chair Yuying Li, University of Waterloo - Invited Session

Yuying Li, University of Waterloo (with Thomas Coleman, Jiong Xi)

A novel method for computing an optimal VaR portfolio

Computing an optimal portfolio with minimum value-at-risk (VaR) is computationally challenging since there are many local minimizers. We consider a nonlinearly constrained optimization formulation directly based on VaR definition in which VaR is defined by a probabilistic inequality constraint. We compute an optimal portfolio using a sequence of smooth approximations to the nonlinear inequality constraint. The proposed sequence of smooth approximations gradually becomes more nonconvex in an attempt to track the global optimal portfolio. Computationally comparisons will be presented to illustrate the accuracy and efficiency of the proposed method.

Qihang Lin, Carnegie Mellon University (with Javier Pena)

First-order algorithms for optimal trade execution with dynamic risk measures

We propose a model for optimal trade execution in an illiquid market that minimizes a coherent dynamic risk of the sequential transaction costs. The prices of the assets are modeled as a discrete random walk perturbed by both temporal and permanent impacts induced by the trading volume. We show that the optimal strategy is time-consistent and deterministic if the dynamic risk measure satisfies a Markov property. We also show that our optimal execution problem can be formulated as a convex program, and propose an accelerated first-order method that computes its optimal solution. The efficiency and scalability of our approaches are illustrated via numerical experiments.

Somayeh Moazeni, Princeton University (with Thomas Coleman, Yuying Li)

Regularized robust optimization for optimal portfolio execution

An uncertainty set is a crucial component in robust optimization. Unfortunately, it is often unclear how to specify it precisely. Thus it is important to study sensitivity of the robust solution to variations in the uncertainty set, and to develop a method which improves stability of the robust solution. To address these issues, we focus on uncertainty in the price impact parameters in the optimal portfolio execution problem. We illustrate that a small variation in the uncertainty set may result in a large change in the robust solution. We then propose a regularized robust optimization formulation which yields a solution with a better stability property than the classical robust solution. In this approach, the uncertainty set is regularized through a regularization constraint. The regularized robust solution is then more stable with respect to variation in the uncertainty set specification, in addition to being more robust to estimation errors in the price impact parameters. We show that

the regularized robust solution can be computed efficiently using convex optimization. We also study implications of the regularization on the solution and its corresponding execution cost.

Game theory

Tue.2.MA 043

Coordination mechanisms for efficient equilibria

Organizer/Chair Tobias Harks, Maastricht University - Invited Session

Laurent Gourves, CNRS (with Bruno Escoffier, Jerome Monnot)

On the price of anarchy of the set cover game

Given a collection C of weighted subsets of a ground set E , the set cover problem is to find a minimum weight subset of C which covers all elements of E . We study a strategic game defined upon this classical optimization problem. Every element of E is a player which chooses one set of C where it appears. Following a public tax function, every player is charged a fraction of the weight of the set that it has selected. Our motivation is to design a tax function having the following features: it can be implemented in a distributed manner, existence of an equilibrium is guaranteed and the social cost for these equilibria is minimized.

Rudolf Müller, Maastricht University (with Birgit Heydenreich, Marc Uetz)

Mechanism design for decentralized online machine scheduling

Traditional optimization models assume a central decision maker who optimizes a global system performance measure. However, problem data is often distributed among several agents, and agents take autonomous decisions. This gives incentives for strategic behavior of agents, possibly leading to sub-optimal system performance. Furthermore, in dynamic environments, machines are locally dispersed and administratively independent. We investigate such issues for a parallel machine scheduling model where jobs arrive online over time. Instead of centrally assigning jobs to machines, each machine implements a local sequencing rule and jobs decide for machines themselves. In this context, we introduce the concept of a myopic best response equilibrium, a concept weaker than the classical dominant strategy equilibrium, but appropriate for online problems. Our main result is a polynomial time, online mechanism that – assuming rational behavior of jobs – results in an equilibrium schedule that is 3.281-competitive with respect to the maximal social welfare. This is only slightly worse than state-of-the-art algorithms with central coordination.

Martin Gairing, University of Liverpool (with Giorgos Christodoulou)

Coordination mechanisms for congestion games

In a congestion game, we are given a set of resources and each player selects a subset of them (e.g., a path in a network). Each resource has a univariate cost (or utility) function that only depends on the load induced by the players that use it. Each player aspires to minimize (maximize) the sum of the resources's cost (utilities) in its strategy given the strategies chosen by the other players.

Congestion games have played a starring role in recent research on quantifying the inefficiency of game theoretic equilibria. Most of this research focused on the price of anarchy.

In this talk, we will discuss coordination mechanisms for congestion games. That is, we study how much we can improve the price of anarchy by certain local modifications to the resource cost/utility functions. We will also discuss when such modifications yield polynomial-time convergence of best-reply dynamics.

Global optimization

Tue.2.H 2053

Rigorous global optimization

Organizer/Chair Arnold Neumaier, University of Vienna - Invited Session

Hermann Schichl, Universität Wien (with Mihaly Markot, Arnold Neumaier)

Balanced rigorous relaxation methods in global optimization

Relaxations are an important tool for solving global optimization problems. Linear and more general convex relaxations are most commonly employed in global optimization algorithms. We present a new relaxation scheme for mixed integer nonlinear programs which balances the dimension of the relaxed problem with its enclosure properties and apply it to generate LP and MIP relaxations of a factorable global optimization problem as well as convex QP and QCQP relaxations.

We generate these relaxations by analyzing the structure of the operational directed acyclic graph of the problem and use a combination of local relaxation at a node of the graph and slope based relaxation methods working on subgraphs. This allows to limit the size of the re-

laxation, hereby reducing the computational effort for the solution of the relaxations during the branch and bound process.

Ferenc Domes, CNRS/LINA UMR 6241 (with Alexandre Goldsztejn)

Finding global robust solutions of robust quadratic optimization problems

In our talk we discuss finding global robust solutions of robust optimization problems having a quadratic cost function and quadratic inequality constraints. The uncertainties in the constraint coefficients are represented using either universal or existential quantified parameters and interval parameter domains. This approach allows to model non-controlled uncertainties by using universally quantified parameters and controlled uncertainties by using existentially quantified parameters. While existentially quantified parameters could be equivalently considered as additional variables, keeping them as parameters allows maintaining the quadratic problem structure, which is essential for our algorithm.

The branch and bound algorithm we present handles both universally and existentially quantified parameters in a homogeneous way without branching on their domains, and uses some dedicated numerical constraint programming techniques for finding the robust, global solution. The algorithm's worst-case complexity is exponential with respect to the number of variables only, even in the case of many and/or large parameters uncertainties.

Arnold Neumaier, University of Vienna (with Ferenc Domes, Mihaly Markot, Hermann Schichl)

Projective methods for constraint satisfaction and global optimization

Many constraint satisfaction problems and global optimization problems contain some unbounded variables. Their solution by branch and bound methods poses special challenges as the search region is infinitely extended. Most branch and bound solvers add artificial bounds to make the problem bounded, or require the user to add these. However, if these bounds are too small, they may exclude a solution, while when they are too large, the search in the resulting huge but bounded region may be very inefficient. Moreover, global solvers that provide a rigorous guarantee cannot accept such artificial bounds.

We present methods based on compactification and projective geometry to cope with the unboundedness in a rigorous manner. Two different versions of the basic idea, namely (i) projective constraint propagation and (ii) projective transformation of the variables, are implemented in the rigorous global solvers COCONUT and GloptLab.

Numerical tests demonstrate the capability of the new technique, combined with standard pruning methods, to rigorously solve unbounded global problems.

Implementations & software

Tue.2.H 1058

Software for constraint programming

Organizer/Chair Paul Shaw, IBM · Invited Session

Paul Shaw, IBM

Automatic search in CP optimizer

Automatic (or autonomous) search is a subject which has gained interest in the CP community over the last few years, in response to a need to simplify the use of constraint programming. IBM (previously ILOG) has been at the forefront of this effort with the implementation of the CP Optimizer component of CPLEX Optimization Studio. CP Optimizer includes in its automatic search procedure diverse elements such as local search, learning techniques, and linear programming. In this talk, we briefly present CP Optimizer and the key elements of its automatic search.

Peter Nightingale, University of St Andrews (with Ian Gent, Christopher Jefferson, Ian Miguel)

Watched literals and generating propagators in constraint programming

Many modern constraint solvers interleave constraint reasoning (propagation) with a complete search. In systems like these, the efficiency of propagation is vital, because the solver spends almost all of its time doing propagation. In this talk I will present a number of techniques developed at St Andrews to improve the efficiency of propagation, in some cases by orders of magnitude.

Watched literals are used in SAT (propositional satisfiability) solvers where they are helpful in dealing with the huge number of long constraints generated by conflict learning. I will discuss porting watched literals to CP, and when this is useful. I will also talk about automatic generation of propagation algorithms, and when this can outperform even hand-optimised algorithms.

Most of the techniques are implemented in the Minion solver. I will give an overview of Minion's features, strengths and weaknesses.

Guido Tack, NICTA / Monash University (with Sebastian Brand, Mark Brown, Thibaut Feydy, Julien Fischer, Maria Garcia de la Banda, Peter Stuckey, Mark Wallace)

Towards MiniZinc 2.0

MiniZinc is a language for modelling combinatorial problems. It aims at striking the right balance between expressiveness on the one hand, and support for different solvers on the other. To this end, MiniZinc provides a library of predicates defining global constraints, and a generic translation to FlatZinc, a low-level language that is easy to support by different solvers.

Since its inception in 2006, MiniZinc has gained considerable momentum. In its current version 1.5, the G12 MiniZinc distribution provides a complete, stable, usable toolchain for modelling and solving combinatorial problems. Its library contains definitions of over 150 global constraints, and there are backends for a variety of different solvers, from constraint programming, to mathematical programming, to SAT and SMT.

The next major milestone will conservatively extend the language with features from full Zinc, add more control over the search, and open up the toolchain to allow for customisation of the translation and easier integration into existing software.

This presentation gives an overview of the MiniZinc system, what is planned for version 2.0, and the techniques required to implement it.

Integer & mixed-integer programming

Tue.2.H 2013

Advances in mixed integer programming

Organizer/Chair Andrea Lodi, University of Bologna · Invited Session

Alejandro Toriello, University of Southern California

Optimal toll design: A lower bound framework for the traveling salesman problem

We propose a framework of lower bounds for the asymmetric traveling salesman problem based on approximating the dynamic programming formulation, and give an economic interpretation wherein the salesman must pay tolls as he travels between cities. We then introduce an exact reformulation that generates a family of successively tighter lower bounds, all solvable in polynomial time, and compare these new bounds to the well-known Held-Karp bound.

Minjiao Zhang, The Ohio State University (with Simge Kucukyavuz)

Cardinality-constrained continuous mixing set

We study the polyhedron of continuous mixing set with a cardinality constraint (CMC), which arises as a substructure of a dynamic decision-making problem under a joint chance constraint. We give valid inequalities and alternative extended formulations for CMC. We develop a branch-and-cut algorithm and test it on a dynamic lot-sizing problem with stochastic demand in which a specific service level must be met over the finite planning horizon. Our computational experience shows that the branch-and-cut algorithm is effective in solving the probabilistic dynamic lot-sizing problems with a moderate number of scenarios.

Ricardo Fukasawa, University of Waterloo (with Ahmad Abdi)

New inequalities for mixing sets arising in chance constrained programming

Luedtke et al (2010) and Kucukyavuz (2010) study a mixing set arising when reformulating chance-constrained programs with joint probabilistic constraints in which the right-hand-side vector is random with a finite discrete distribution. These two papers introduce facet-defining inequalities for the convex hull of such sets, like the strengthened star inequalities and the (T, Π_L) inequalities. We present a new class of inequalities that generalizes all these previously derived inequalities (both for the equal and unequal probabilities case).

Integer & mixed-integer programming

Tue.2.H 2032

Trends in mixed integer programming III

Organizers/Chairs Robert Weismantel, ETH Zurich; Andrea Lodi, University of Bologna · Invited Session

Qie He, Georgia Tech ISyE (with Shabbir Ahmed, George Nemhauser)

Minimum concave cost network flow over a grid network

The minimum concave cost network flow problem (MCCNFP) is NP-hard, but efficient polynomial-time algorithms exist for some special cases, such as the uncapacitated multi-echelon lot-sizing problem. We consider the computational complexity of MCCNFP as a function of the underlying network topology and the representation of the concave

function by studying MCCNFP over a grid network with a general non-negative separable concave function. We show that this problem is polynomially solvable when all source nodes are at the first echelon and all sink nodes are at the last echelon. The polynomiality argument relies on a combination of a particular dynamic programming formulation and a careful investigation of the extreme points of the underlying flow polyhedron. We derive an analytical formula for the inflow of any node under all extreme points, which generalizes Zangwill's result for the multi-echelon lot-sizing problem.

Tamás Kis, MTA SZTAKI

Strengthening the MIP formulation of a bilevel lot-sizing problem

In the talk, I will introduce the bilevel lot-sizing problem, and show how to formulate it as a MIP. In addition, I will present problem specific bounds and cuts, as well as mixed integer disjunctive cuts derived from two rows of the simplex tableau, one corresponding to an integer variable, the other to a continuous variable. I will also discuss the computational merits of the various strengthening methods.

Fabio Furini, Università di Bologna (with Manuel Iori, Silvano Martello, Mutsunori Yagiura)

Heuristic and exact algorithms for the interval min-max regret knapsack problem

We consider a generalization of the 0-1 knapsack problem in which the profit of each item can take any value in a range characterized by a minimum and a maximum possible profit. A set of specific profits is called a scenario. The *interval min-max regret knapsack problem* (MRKP) is then to find a feasible solution such that the maximum regret over all scenarios is minimized. The problem is extremely challenging both from a theoretical and a practical point of view. Its recognition version is complete for the complexity class Σ_2^P hence it is most probably not in \mathcal{NP} . In addition, even computing the regret of a solution with respect to a scenario requires the solution of an \mathcal{NP} -hard problem. We examine the behavior of classical combinatorial optimization approaches when adapted to the solution of the MRKP. We introduce an iterated local search approach and a Lagrangian-based branch-and-cut algorithm, and evaluate their performance through extensive computational experiments.

Life sciences & healthcare

Tue.2.H 2033

Bioinformatics and combinatorial optimization II

Organizer/Chair Gunnar Klau, CWI · Invited Session

Johannes Köster, University Duisburg-Essen (with Sven Rahmann, Eli Zamir)

Protein hypernetworks

Protein interactions are fundamental building blocks of biochemical reaction systems underlying cellular functions. The complexity and functionality of such systems emerge not only from the protein interactions themselves but mainly from the dependencies between these interactions, e.g., due to allosteric regulation or steric hindrance. Therefore, a comprehensive approach for integrating and using information about such dependencies is required. We present an approach for endowing protein networks with interaction dependencies using propositional logic, thereby obtaining protein hypernetworks. As can be expected, this framework straightforwardly improves the prediction of protein complexes. We found that modeling protein perturbations in hypernetworks, rather than in networks, allows to better infer also the functional necessity and synthetic lethality of proteins in yeast.

Gunnar Klau, CWI (with Stefan Canzar, Mohammed El-Kebir, Khaled Elbassioni, Daan Geerke, Alpesh Malde, Alan Mark, René Pool, Leen Stougie)

Charge group partitioning in biomolecular simulation

Molecular simulation techniques are increasingly being used to study biomolecular systems at an atomic level. Such simulations rely on empirical force fields to represent the intermolecular interactions. There are many different force fields available, each based on a different set of assumptions and thus requiring different parametrization procedures. Recently, efforts have been made to fully automate the assignment of force-field parameters, including atomic partial charges, for novel molecules. In this work, we focus on a problem arising in the automated parametrization of molecules for use in combination with the GROMOS family of force fields: namely, the assignment of atoms to charge groups such that for every charge group the sum of the partial charges is ideally equal to its formal charge. In addition, charge groups are required to have size at most k . We show NP-hardness and give an exact algorithm capable of solving practical problem instances to provable optimality in a fraction of a second.

Rumen Andonov, INRIA and University of Rennes 1 (with Gunnar Klau, Inken Wohlers)

Optimal DALI protein structure alignment

We present a mathematical model and exact algorithm for optimally aligning protein structures using DALI score, which is an NP-hard prob-

lem. DALI score is based on comparing the inter-residue distance matrices of proteins, and is the scoring model of a widely used heuristic. We extend an integer linear programming approach which has been previously applied for the related, but simpler, contact map overlap problem. To this end, we introduce a novel type of constraint that handles negative score values and relax it in a Lagrangian fashion. The new exact algorithm is thus applicable to any distance matrix-based scoring scheme. Using four known data sets of varying structural similarity, we compute many provably optimal alignments. Thus, for the first time, we evaluate and benchmark the popular heuristic in sound mathematical terms. The results indicate that usually the heuristic computes optimal or close to optimal alignments. However, we detect an important subset of small proteins for which DALI fails to generate any significant alignment, although such alignments do exist.

Logistics, traffic, and transportation

Tue.2.H 0106

Hub location problems

Chair Julia Sender, TU Dortmund University

Julia Sender, TU Dortmund University (with Uwe Clausen)

A local improvement heuristic for a hub location problem in wagonload traffic

In wagonload traffic, single wagons with different origins and destinations are consolidated on their routes through the railway network. The consolidation of wagons decreases the transportation costs but increases additional costs due to establishing and operating hub facilities. We present a specific capacitated multiple allocation hub location problem for the strategic network design of wagonload traffic developed together with our partner Deutsche Bahn AG. The model covers the main characteristics of wagonload traffic. Due to the difficulty to solve real-sized instances to (near-) optimality, we develop a new heuristic solution approach. The presented heuristic approach is based on local improvements (obtained, e. g. by relocation, opening, or closure of hub nodes or reallocation of non-hub nodes to hub nodes). We solve the problem with the heuristic approach and CPLEX on test data sets obtained from Deutsche Bahn. The computational results are presented and compared.

Vinicius Armentano, Universidade Estadual de Campinas (with Ana Milanez)

Tabu search for the hub covering problem

Hub location is an important research area due to the use of hub networks in transportation and telecommunication systems that serve demand for goods or information between many origins and many destinations. Instead of serving every origin-destination demand with a direct link, hubs are used to switch and consolidate origin-destination flows, thus reducing the number of links in the network and allowing economies of scale to be exploited. As a consolidation point, flows from the same origin with different destinations are consolidated on their route to the hub and are combined with flows that have different origins but the same destination. We address the covering hub location problem which ensures that in hub networks goods between any origin and any destination are delivered within a given time limit, an important service constraint for less-than-truckload carriers. The objective is to minimize the number of hubs to be opened. Existing research on this problem has focused on the development of tighter integer programming models, which are solved by a solver. We propose a tabu search procedure for solving this problem, and the procedure is tested on instances from the literature.

Hiroaki Mohri, Waseda University

Some extended network hub problems

Network hub (location) problems (NHP), also called "hub network design problems", have many applications in the real world especially, telecommunication and transportation. We would like to introduce some 'extended' NHPs. In this presentation, we address NHPs with the following additional conditionals independently.

- (i) Network flow capacity on each arc.
- (ii) The number of hubs should not be fixed a constant p . (No constraints. Otherwise, inequality constraints.)
- (iii) On each path for demand, i.e., commodity, hubs should be located within k -arcs from its sink and source.

Basically, this extended problem is something like "multi-commodity min flow problem" with "hub location problem". We would like to show a general formulation for this problem and polynomial time algorithms for special graphs. And we shall show some results for some hierarchical NHPs.

Logistics, traffic, and transportation

Tue.2.H 0111

Logistics and network optimization: New problems and new approaches

Organizers/Chairs Frieda Granot, University of British Columbia; Daniel Granot, Sauder School of Business · Invited Session

Alexander Richter, TU-Berlin (with Tobias Harks, Felix König, Jannik Matuschke, Jens Schulz)

An integrated approach to tactical logistics network optimization

In global logistics operations, tactical planning aims at laying the groundwork for cost-efficient day-to-day operation by deciding on transport modes, routes, and delivery frequencies between facilities in the network. We consider a fixed charge multi-commodity network flow model to optimize supply chains on the tactical level, that is, the infrastructure is already in place and we seek cost optimal transport and storage modes. Model characteristics include a frequency pattern expansion to capture the tradeoff between inventory costs and economies of scale for transport costs, as well as multidimensional commodity properties and complex tariff structures. We devise local search type and combinatorial heuristics that can be combined with mixed integer programming techniques. To evaluate the quality of these approaches we present a computational study on a set of large-scale real-world instances provided by our industrial cooperation partner. The model and the obtained results are part of the MultiTrans project, a cooperation between the COGA chain at TU Berlin and 4flow AG, a market leader in logistics and supply chain management consulting.

Michal Penn, Technion (with N. Druker, O. Strichman)

Cyclic routing of unmanned aerial vehicles

Developing autonomous monitoring systems for Unmanned Aerial Vehicles (UAVs), which facilitate scanning and monitoring a set of targets on the ground is of growing interest in security applications. These monitoring systems have to support complex tasks that include multiple UAVs that should scan and monitor multiple distant predefined targets, with a known distance matrix, in cyclic routes. Each target is associated with a temporal constraint, namely, a relative deadline, that is, the maximum permitted time interval between two successive scanning of the target. Our aim is to determine the minimum number of UAVs required for suitable cyclic route that visits, under the temporal constraints all targets. We formulate the problem as MILP and as Satisfiability Modulo Theories (SMT) problem. We use several solutions methods, such as Mosek, Z3 and DFS and demonstrate their numerical results

Tal Raviv, Tel Aviv University (with Gil Einy)

Optimal control of battery switching stations

We introduce a new on-line scheduling problem motivated by the business model of Better Place Ltd. The company sells electric vehicles (EV) with replaceable Lithium Ion batteries and provides battery replacement services in Battery Switching Stations (BSS). The BSS Scheduling Problem is defined as follows: a stream of requests for battery switches to be fulfilled is governed by a known, non-homogenous, stochastic process. The disassembled batteries are recharged and used to fulfill future requests. Partly charged batteries can be supplied at a penalty cost that depends on their charging level. The charging duration and power consumption during the process varies depending on the battery and charging technologies. The cost of electricity and the maximum allowed power consumption varies during the planning horizon. The operational goal is to establish a charging policy so as to minimize the expected total electricity and penalty costs. We develop an on-line heuristic for the BSS problem, based on an efficient algorithm for a deterministic version of this problem, and demonstrate its efficiency by an extensive numeric experiment in a realistic setting.

Mixed-integer nonlinear programming

Tue.2.MA 005

Advances in MINLP

Organizer/Chair Sarah Drewes, T Systems International GmbH · Invited Session

Tamás Terlaky, Lehigh University (with Pietro Belotti, Julio Goez, Imre Pólik, Ted Ralphs)

Conic representation of the convex hull of disjunctions of convex sets and conic cuts for mixed integer second order cone optimization

This talk gives some insight of how to design disjunctive conic cuts for mixed integer conic linear optimization problems. The novel disjunctive conic cuts may be used to design branch-and-cut algorithms for CLO problems.

Second order conic optimization (SOCO) has been the subject of intense study in the past two decades. Interior point methods (IPMs) provide polynomial time algorithms in theory, and powerful software tools in computational practice. Just as in linear and nonlinear optimization, the use of integer variables naturally occur in SOCO. Thus, the need for dedicated mixed integer SOCO algorithms and software is evident.

We present efficiently computable disjunctive conic cuts for MISOCO problems. The novel disjunctive conic cuts may be used to design branch-and-cut algorithms for MISOCO. Finally, some illustrative, preliminary computational results as presented when disjunctive conic cuts are used in solving MICOSO problems.

Sarah Drewes, T Systems International GmbH (with Alper Atamtürk)

Cover inequalities and outer-approximation for mixed-01 SOCPs

We present how cover inequalities can be utilized in outer approximation based branch and bound algorithms for mixed 0 – 1 convex nonlinear programming problems in general and show more specific results for a class of mixed 0 – 1 second order cone programs. The discussed class of algorithms use an outer approximation of the mixed 0-1 problem arising from linearizations of the nonlinear functions. Based on this outer approximations, assignments for the binary variables are derived which give rise to valid cover inequalities. These inequalities can then be lifted to derive strong valid inequalities that tighten the continuous relaxation of the outer approximation problem. The potential of this approach is discussed considering a class of mixed 0 – 1 second order cone programs for which a computational study is provided.

Antonio Morsi, FAU Erlangen-Nürnberg, Discrete Optimization (with Bjoern Geisler, Alexander Martin, Lars Schewe)

Solving MINLPs on loosely coupled networks

Considering MINLPs defined on a network structure, such as nonlinearly-constrained network flow problems, we obtain dual bounds on the overall problem by a decomposition of the underlying graph into its biconnected and triconnected components and by the relaxation of the coupling constraints between these components. The dual bounds are further tightened by branching on violated nonconvex constraints. Branching candidates are obtained from an approximate primal solution to the master problem, which is solved by a bundle method. To solve the subproblems, in the case of factorable MINLPs, we use Chebyshev approximation to compute univariate piecewise linearizations (or piecewise polynomials) of the arising nonlinearities in advance. These approximations lead to MILP relaxations, or mixed integer polynomial relaxations, of the subproblems. We conclude with computational results of our approach for two real-world applications, water and gas network optimization.

Multi-objective optimization

Tue.2.H 1029

Interactive multiobjective optimization

Organizer/Chair Kaisa Miettinen, University of Jyväskylä and KTH Royal Institute of Technology · Invited Session

Martin Geiger, Helmut-Schmidt-University (with Thibaut Barthélemy, Marc Sevaux)

Multi-objective inventory routing: Reference-point-based search, representations, and neighborhoods

The talk considers a multi-objective generalization of the inventory routing problem, a problem arising in transportation/the physical distribution of goods. In our problem formulation, inventory levels and routing costs are not combined into an overall evaluation function but treated separately. The problem is solved by the use of metaheuristics, and numerical results are computed and reported.

Particular emphasis has been laid on the representation of solutions from a practical point of view. In detail, individual frequency values are derived for each customer, implementing a recurring delivery policy. On the one hand, this leads to a relatively easy, understandable encoding of delivery policies. On the other hand however, the possibilities of the optimization approach are depending on the chosen representation, and interrelations with the chosen neighborhoods and search-/optimization-strategies become apparent.

Our findings show that there is great potential for tradeoffs between the two objectives. Especially in tactical planning situations, this problem extension can provide useful insights. A DSS making use of multiple reference points has thus been realized.

Kaisa Miettinen, University of Jyväskylä and KTH Royal Institute of Technology (with Markus Hartikainen, Kathrin Klamroth)

Interactive Pareto Navigator method for nonconvex multiobjective optimization

We describe a new interactive method called Nonconvex Pareto Navigator which extends the convex Pareto Navigator method for non-convex multiobjective optimization problems. In the new method, a piecewise linear approximation of the Pareto optimal set is first generated using a relatively small set of Pareto optimal solutions. The decision maker (DM) can then navigate on the approximation and direct the search for interesting regions in the objective space. In this way, the DM can conveniently learn about the interdependencies between the conflicting objectives and possibly adjust one's preferences. Besides non-convexity, the new method contains more versatile options for directing

the navigation. The Nonconvex Pareto Navigator method aims at supporting the learning phase of decision making. It is well-suited for computationally expensive problems because the navigation is computationally inexpensive to perform on the approximation. Once an interesting region has been found, the approximation can be refined in that region or the DM can ask for the closest actual Pareto optimal solution.

Hans Trinka, Fraunhofer ITWM

Multi criteria decision support in real-time

Integration of Project, Process and Knowledge Management. The business processes observed here affect various organizational units during evolving in successive phases. A few examples to that: surveillance and maintenance of ship equipment, transport logistics of wind wheel parts, and innovation of OLED technology. At certain stations of those processes several things have to be done: knowledge retrieval and storage, working out of prescribed context relevant documents or performing situation dependent programs, and exploring and evaluating various feasible scenarios. Again some examples: time- or cost-optimal remedying of a ship's defect, selecting, assimilating and tracking of conveyor chains, and designing and simulating product or shop floor prototypes. In finding "best paths" through such dynamic processes two tools, addressing the outstanding visual cognition of man, assist: "process-Board", for designing, adapting, monitoring and controlling processes on a virtual board, and "knowCube", for getting balanced decisions by using graphical means, applicable by non-experts, too. Both tools are combined in a web portal.

Nonlinear programming

Tue.2.H 0107

Methods for nonlinear optimization V

Chair Marco Rozgic, Helmut-Schmidt-University Hamburg

Manuel Jaraczewski, Helmut-Schmidt-Universität - Universität der Bundeswehr Hamburg (with Marco Rozgic, Marcus Stierner)

Interior point methods for a new class of minimum energy point systems on smooth manifolds

Point systems with minimum discrete Riesz energy on smooth manifolds are often considered as good interpolation and quadrature points. Their properties have intensively been studied, particularly for the sphere and for tori. However, these points do not optimally fast converge to the corresponding equilibrium distribution, since the continuous potential's singularity is poorly reproduced. We, hence, propose an alternative point system that avoids this problem and we provide a method for its numerical identification via constrained optimization with an interior point method. The key idea is dividing the points into two classes and considering them as vertices of a graph and its dual, respectively. Geometric relations between primal faces and dual vertices serve as constraints, which additionally stabilize the optimization procedure. Further, a prior global optimization method as usually applied for computing minimum discrete Riesz energy points can be avoided. Finally, for the new determined extreme points both approximation properties and efficient determinability are studied and compared to those of the minimum discrete Riesz energy points.

Marco Rozgic, Helmut-Schmidt-University Hamburg (with Robert Appel, Marcus Stierner)

Interior point methods for the optimization of technological forming processes

Recent results in forming technology indicate that forming limits of classical quasi-static forming processes can be extended by combining them with fast impulse forming. However, in such combined processes, parameters have to be chosen carefully, to achieve an increase in formability. In previous works a gradient based optimization procedure as well as a simulation framework for the coupled process has been presented. The optimization procedure strongly depends on the linearization of the full coupled problem, which has to be completely simulated for gradient- and function- evaluation. In order to gain insight into the structure of the underlying optimization problem we analyse parameter identification an elastic deformation problem. Within this framework all needed derivative information is analytically computable and optimality conditions can be proved. This is used to perform systematic studies of properties and behaviour of the problem. We show that replacing derivative information with finite difference approximations requires additional constraints in order to retain physical feasibility. Finally we extend the developed scheme by introducing a plasticity model.

Nonlinear programming

Tue.2.H 0110

Nonlinear optimization V

Organizers/Chairs Frank E. Curtis, Lehigh University; Daniel Robinson, Johns Hopkins University · Invited Session

Denis Ridzal, Sandia National Labs (with Miguel Aguilo, Joseph Young)

A matrix-free trust-region SQP algorithm for large-scale optimization

We present an inexact trust-region sequential quadratic programming (SQP) method for the matrix-free solution of large-scale nonlinear programming problems. First, we discuss recent algorithmic advances in the handling of inequality constraints. Second, for optimization problems governed by partial differential equations (PDEs) we introduce a class of preconditioners for optimality systems that are easily integrated into our matrix-free trust-region framework and that efficiently reuse the available PDE solvers. We conclude the presentation with numerical examples in acoustic design, material inversion in elastodynamics and optimization-based failure analysis.

Anders Forsgren, KTH Royal Institute of Technology

Inexact Newton methods with applications to interior methods

Newton's method is a classical method for solving a nonlinear equation. We discuss how Jacobian information may be reused without sacrificing the asymptotic rate of convergence of Newton's method. In particular, we discuss how inexact Newton methods might be used in the context of interior methods for linear and convex quadratic programming.

Wenwen Zhou, SAS Institute Inc. (with Joshua Griffin)

Numerical experience of a primal-dual active set method and its improvement

SAS has recently developed and implemented a multi-threaded Krylov-based active set method based on the exact primal dual augmented Lagrangian merit function of P. E. Gill and D. Robinson [1] for large-scale nonconvex optimization. The merit function has several attractive properties, including a dual regularization term that effectively relaxes restrictions for what preconditioner types can be used with the corresponding Newton equations. Numerical experience and strategies for improving convergence for this approach will be reported in this talk.

[1] P. E. Gill and D. P. Robinson, A Primal Dual Augmented Lagrangian, Department of Mathematics, University of California San Diego. Numerical Analysis Report 08-2.

Nonlinear programming

Tue.2.H 0112

Real-time optimization II

Organizers/Chairs Victor Zavala, Argonne National Laboratory; Sebastian Sager, Universität Magdeburg · Invited Session

Mihai Anitescu, Argonne National Laboratory (with Victor Zavala)

Scalable dynamic optimization

In this talk, we discuss scalability issues arising in dynamic optimization problems such as model predictive control and data assimilation. We present potential strategies to avoid them, where we focus on scalable algorithms for methods that can track the optimal manifold with even one quadratic program per step. This builds on recent work of the authors where we proved using a generalized equations framework that such methods stabilize model predictive control formulation even when they have explicit inequality constraints. In particular, we present alternatives to enable fast active-set detection and matrix-free implementations.

Christian Kirches, University of Chicago / University of Heidelberg (with Hans-Georg Bock, Sebastian Sager)

A real-time iteration scheme for mixed-integer nonlinear model predictive control

A class of nonlinear model predictive control problems with both continuous and binary controls is considered. Partial outer convexification and relaxation is used to obtain a continuous model predictive control problem with possibly increased control dimension. The problem can then be solved by combining a direct method for optimal control with a rounding scheme. Feasibility and optimality certificates hold, while numerical computations typically do not involve an exponential runtime effort. It is argued that the idea of real-time iterations proposed by Diehl et al. can be used to devise a new mixed-integer real-time iteration scheme for this problem class. To this end, it is shown that adding a rounding step to one iteration of the scheme can be interpreted as carrying out a step of a perturbed Newton-type method. Sufficient conditions for local contractivity of such a perturbed method are derived. Based on this local contractivity argument, a proof of locally

asymptotic convergence of the proposed scheme on a receding horizon is given for the nonlinear discrete-time case. An upper bound on the allowable sampling time of the scheme and on the loss of optimality is derived.

Francesco Borrelli, UC Berkeley (with Matusko Jadranko, Yudong Ma)

Real-time stochastic predictive control applied to building control systems

The presentation will focus on the solution of linear stochastic model predictive control (SMPC) subject to joint chance constraints. We present and compare two approaches. In the the explicit approach a set of unknowns representing allowable violation for each constraint (the risk) is introduced. A tailored interior point method is proposed to explore the special structure of the resulting SMPC problem computing the input sequence and the risk allocation. In the sample-based approach, a large number of stochastic samples is used to transform the SMPC problem into a deterministic one with the original constraints evaluated in every sample. The proposed methods are applied to a building control problem which minimizes energy usage while keeping zone thermal comfort by using uncertain prediction of thermal loads and ambient temperature. Extensive numerical and experimental tests are used to analyze the conservatism and the effectiveness of the proposed approaches.

Nonsmooth optimization

Tue.2.H 1012

Nonsmooth optimization methods

Organizer/Chair Alain Pietrus, Université des Antilles et de la Guyane · Invited Session

Alain Pietrus, Université des Antilles et de la Guyane

Some methods for solving perturbed variational inclusions

This paper deals with variational inclusions of the form $0 \in f(x) + g(x) + F(x)$ where f is a Fréchet differentiable function, g is a Lipschitz function and F is a set-valued map acting in \mathbb{R}^n .

In a first time in this talk, we recall some existing results in relation with metric regularity. In a second time, we focus on the case where the set valued map F is a cone and in this case we introduce different algorithms to approximate a solution x^* of the variational inclusion. Different situations are considered: the case where g is smooth, the case where g is semi-smooth (existence of differences divided, ...) and the case where g is only Lipschitz. We show the convergence of these algorithms without the metric regularity assumption.

Christopher Hendrich, Chemnitz University of Technology (with Radu Bot)

A double smoothing technique for solving nondifferentiable convex optimization problems

The aim of this talk is to develop an efficient algorithm for solving a class of unconstrained nondifferentiable convex optimization problems. To this end we formulate first its Fenchel dual problem and regularize it in two steps into a differentiable strongly convex one with Lipschitz continuous gradient. The doubly regularized dual problem is then solved via a fast gradient method with the aim of accelerating the resulting convergence scheme.

Emil Gustavsson, Chalmers University of Technology (with Michael Patriksson, Ann-Brith Strömberg)

Primal convergence from dual subgradient methods for convex optimization

When solving a convex optimization problem through a Lagrangian dual reformulation subgradient optimization methods are favourably utilized, since they often find near-optimal dual solutions quickly. However, an optimal primal solution is generally not obtained directly through such a subgradient approach. We construct a sequence of convex combinations of primal subproblem solutions, a so called ergodic sequence, which is shown to converge to an optimal primal solution when the convexity weights are appropriately chosen. We generalize previous convergence results from linear to convex optimization and present a new set of rules for constructing the convexity weights defining the ergodic sequence of primal solutions. In contrast to rules previously proposed, they exploit more information from later subproblem solutions than from earlier ones. We evaluate the proposed rules on a set of nonlinear multicommodity flow problems and demonstrate that they clearly outperform the previously proposed ones.

Optimization in energy systems

Tue.2.MA 549

Stochastic programming applications in energy systems

Organizer/Chair Suvrajeet Sen, University of Southern California · Invited Session

Cosmin Petra, Argonne National Laboratory (with Mihai Anitescu, Miles Lubin)

Scalable stochastic optimization of power grid energy systems

We present a scalable approach for solving stochastic programming problems, with application to the optimization of power grid energy systems with supply and demand uncertainty. Our framework, PIPS, has parallel capabilities for both continuous and discrete stochastic optimizations problems. The continuous solver uses an interior-point method and a Schur complement technique to obtain a scenario-based decomposition. With an aim of providing a scalable solution for problems with integer variables, we also developed a linear algebra decomposition strategy for simplex methods that is used in a parallel branch-and-bound framework.

We will also discuss application-specific algorithmic developments and computational results obtained on "Intrepid" Blue Gene/P system at Argonne when solving unit commitment problems with billions of variables.

Diego Klabjan, Northwestern University (with Frank Schneider, Ulrich Thonemann)

Day ahead stochastic unit commitment with demand response and load shifting

High costs for fossil fuels and increasing shares of intermittent energy sources are imposing big challenges on power grid management. Uncertainty in generation as well as in demand for electric energy call for flexible generation capacity and stochastic optimization of generation schedules. Emerging smart grid technology is one component believed to be a successful tool to increase efficiency in power generation and to mitigate effects of increasing uncertainty. We focus on the potential of demand side resources (DSRs) that can be dispatched to reduce load at peak times. We present a stochastic dynamic programming model for the unit commitment problem in a day ahead market and include dispatch decisions for DSRs. We model the effect of load shifting to previous and subsequent periods that must be taken into account when making dispatch decisions. We also present an approximate dynamic programming algorithm embedded in a decomposition algorithm that enables us to capture effects of DSR dispatch on previous periods and to solve both problems concurrently. Lower bounds on the optimal solution are developed.

Boris Defourny, Princeton University (with Ethan Fang, Warren Powell, Hugo Simao)

A quantile-based approach to unit commitment with wind

Handling higher levels of uncertainty in the unit commitment problem (UC) is an important issue for the independent system operator (ISO) who is dealing with an increasing level of variable energy resources (VERs), and specifically energy from wind. Here, we focus on approximations that plan for uncertainty by adding to the original problem new penalties or constraints, and then view the weights of the new terms as tunable parameters. We investigate methods where the wind energy seen by the UC problem is a certain quantile of the forecasted wind distribution. The quantiles are then tuned based on a simulation of the recourse costs. The work is motivated by an analogy with newsvendor-type problems where the overage and underage costs of wind energy forecasts have to be estimated, given a day-ahead schedule.

Optimization in energy systems

Tue.2.MA 550

Stochastic programming models for electricity generation planning

Organizer/Chair Michel Gendreau, École Polytechnique de Montréal · Invited Session

Oscar Carreno, XM S.A.E.S.P (with Jaime Castillo, Carlos Correa)

Developing optimization software for Colombian power system planning

Motivated by the liberalization process of electricity markets led by Chile in 1982 and followed by England and Wales in 1990 and Norway in 1991, Colombia restructured its electricity industry in 1995 evolving to a novel electricity market in the region based on price offers. From then until now, several market rules have changed and evolved, causing modifications in the optimization planning models used for system operation. As a result, the system operator has improved and developed new models and strategies in order to be timely at the forefront of the changing market. XM, Colombian Independent System Operator (ISO), has led this assignment, using state-of-the-art commercial optimization software. Therefore, the optimization models used by XM to plan short- and very short-term have been developed by its own I+D team. This paper presents both, the IT and mathematical formulation, for the most important models developed and daily used by XM, and also show-

ing the benefits and gains derived from their usage that have allowed XM to be pioneer among others Latin America's ISOs.

Raphael Gonçalves, UFSC – LabPlan (with Edson da Silva, Erlon Finardi)

Analyzing multistage stochastic optimization methods to solve the operation planning problem of hydrothermal systems

The operation planning of hydrothermal systems is, in general, divided into coordinate steps which have different horizons and prioritizes distinct details of the modeling. The medium-term operation planning (MTO) problem, one of the operation planning steps of hydrothermal systems and the focus of this work, aims to define the weekly generation for each plant, regarding the uncertainties related to water inflows to reservoirs, to obtain the minimum expected operational cost over a specific period. Solving this problem requires a high computational effort and, consequently, the use of multistage stochastic programming algorithms. Therefore, the main purpose of this work is to present a comparative study about the performance of different multistage stochastic optimization methods applied to the MTO: Nested decomposition (ND) and the progressive hedging (PH) method. With respect to PH method, the algorithm properties and the problem features are studied to assess suitable decomposition schemes to obtain lower CPU time. To evaluate the performance of the both algorithm regarding its particularities, the Brazilian hydrothermal system is studied.

Michel Gendreau, École Polytechnique de Montréal (with Fabian Bastin, Pierre-Luc Carpentier)

Midterm hydro generation scheduling under inflow uncertainty using the progressive hedging algorithm

Hydro-Québec, one of the largest electric utilities in North America, generates virtually all of its power supply using hydro plants. A key problem faced by planners is the midterm generation scheduling problem (MGSP), solved on a weekly basis, in which generation targets must be set for controllable hydro plants in order to manage reservoir energy storage efficiently over the coming months. Reservoir inflows are the main source of uncertainty to account for in the decision-making process. In this paper, we model reservoir inflow uncertainty through scenario trees. We tackle the MGSP using the progressive hedging algorithm (PHA) (Rockafellar and Wets 1991). In our model, hydroelectric generation is given by concave piecewise-linear functions of the upstream reservoir storage and of water release. A key feature of our implementation of the PHA is a new penalty parameter update formula. We assess our model and algorithm on Hydro-Québec's power system (21 large reservoirs and 25 hydro plants) over a 93-week planning horizon with several load levels. Reservoir inflow uncertainty is modeled by a 16-scenario tree. Computational results show that the proposed approach is promising.

PDE-constrained opt. & multi-level/multi-grid meth.

Tue.2.MA 415

Optimization applications in industry I

Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics · Invited Session

Jürgen Sprekels, WIAS Berlin

Optimal control problems arising in the industrial growth of bulk semiconductor single crystals

The industrial growth of bulk semiconductor crystals is a challenging technological problem that leads to control problems with pointwise state constraints for an extremely difficult system of nonlinearly coupled partial differential equations. Turbulent fluid flows, magnetic fields and quasilinear heat conduction problems with both nonlocal and nonlinear radiation boundary conditions occur. We report on recent progress that has been made in the treatment of such problems.

Simon Stingelin, Endress+Hauser Flowtec AG (with Fredi Tröltzsch)

Applications of optimal control in electromagnetic flow measurement

Electromagnetic flow measurement has been in use around the world for more than 50 years, as witnessed by the popularity of these meters that continues unabated in virtually all sectors of industry. Electromagnetic flowmeters can be used to measure all electrically conductive liquids ($>5 \mu\text{S/cm}$) with or without solids.

The volume flow measurement is performed differentially with a pulsed magnetic field to suppress noise voltages as efficiently as possible. The key question in the talk is: How should the coil voltage be controlled to switch as fast as possible from one field state to another?

Because we want to control the voltage in an induction coil, this question leads us to the optimal control of an eddy current problem coupled with an ordinary differential equation for the electrical current. The ordinary differential equation is derived from the induction law.

In the talk we present the necessary first order optimality conditions of the control system and mention the well-posedness. Then we discuss

numerical methods used to calculate the optimal coil voltage. Finally we present computations based on industrial flow meter geometries.

Oliver Tse, TU Kaiserslautern (with René Pinnau)

Optimal boundary control of natural convection-radiation model in melting furnaces

In this paper we present a comprehensive analysis of an optimal boundary control for a combined natural convection-radiation model, which has applications in the design of combustion chambers or for the control of melting processes in glass production or crystal growth. The model under investigation consists of the transient Boussinesq system coupled with a nonlinear heat equation and the SP_3 model for radiation. We present existence, uniqueness and regularity results of bounded states. We further state an analysis of an optimal control problem, where we show the existence of an optimal control, derive the first-order optimality system and analyze the adjoint system. To underline the feasibility of the approach, we present numerical results based on a descent method using adjoint information.

Robust optimization

Tue.2.MA 004

Applications of robust optimization I

Organizer/Chair Dick Den Hertog, Tilburg University · Invited Session

Ihsan Yanikoglu, Tilburg University (with Dick Den Hertog)

Robust simulation-based optimization with Taguchian regression models

A Taguchian way to deal with uncertain environmental parameters in simulation-based optimization is to create a regression model in both the optimization variables and the uncertain parameters, and then formulate the explicit optimization problem in terms of expectations and variances, or chance constraints. The disadvantages of this approach are that one has to assume that the distribution function for the uncertain parameters is normally distributed, and that both the mean and variance are known. The final solution may be very sensitive to these assumptions. We propose a Robust Optimization approach that do not need these assumptions. Based on historical data, uncertainty regions for the distribution is generated, and tractable robust counterparts are generated. This approach can be used for many types of regression models: polynomials, Kriging, etc. The novel approach is illustrated through numerical examples. Finally, for those simulation-based optimization problems that contain 'wait-and-see' variables, we describe how to apply Adjustable Robust Optimization.

Yudong Chen, The University of Texas at Austin (with Constantine Caramanis, Shie Mannor)

Robust sparse regression and orthogonal matching pursuit

We consider support recovery in sparse regression, when some number n_1 out of $n + n_1$ total covariate/response pairs are arbitrarily corrupted. We are interested in understanding how many outliers, n_1 , we can tolerate, while identifying the correct support. As far as we know, neither standard outlier rejection techniques, nor recently developed robust regression algorithms (that focus only on corrupted response variables) provide guarantees on support recovery. Perhaps surprisingly, we also show that the natural brute force algorithm that searches over all subsets of n covariate/response pairs, and all subsets of possible support coordinates in order to minimize regression error, is remarkably poor, unable to correctly identify the support with even $n_1 = O(n/k)$ corrupted points, where k is the sparsity, and p is the dimension of the signal to be recovered. In this setting, we provide a simple algorithm that gives stronger performance guarantees, recovering the support with up to $n_1 = O(n/(\sqrt{k} \log p))$ corrupted points. Moreover, we compare our formulation with robust optimization, and demonstrate interesting connection and difference between them.

Tsan Sheng Ng, National University of Singapore (with Sy Chartle, Myunseok Cheong, Melvyn Sim, Lu Xu)

Target-oriented robust optimization for gas field development planning

Gas field development projects involve both investment and operation decisions, including field infrastructure installation, capacity expansions, and gas extraction planning. Many of these decisions are very expensive, difficult to reverse, and have long-term impacts on the company's profitability. In this work we consider an offshore gas field development planning problem to achieve a target net present value at the end of the planning horizon as well as possible. This problem is severely plagued by endogenous uncertainty that is found in the efficacy of gas well reserves. Inspired by robust optimization, we develop a model that maximizes the robustness of the development plan against uncertainty. The characteristics of the problem lead us to identify an equivalent deterministic mixed integer programming model of polynomial size, which enables us to obtain solutions to realistic size problems. Our computa-

tional tests show that the proposed model significantly improves target attainment and performs favourably in different problem instances.

Robust optimization

Tue.2.MA 042

Advances in robust optimization

Organizer/Chair Daniel Kuhn, Imperial College London · Invited Session

Huan Xu, National University of Singapore (with Constantine Caramanis, Shie Mannor)

A distributional interpretation of robust optimization, with applications in machine learning

Motivated by data-driven decision making and sampling problems, we investigate probabilistic interpretations of Robust Optimization (RO). We establish a connection between RO and Distributionally Robust Stochastic Programming (DRSP), showing that the solution to any RO problem is also a solution to a DRSP problem. Specifically, we consider the case where multiple uncertain parameters belong to the same fixed dimensional space, and find the set of distributions of the equivalent DRSP. The equivalence we derive enables us to construct RO formulations for sampled problems (as in stochastic programming and machine learning) that are statistically consistent, even when the original sampled problem is not. In the process, this provides a systematic approach for tuning the uncertainty set. Applying this interpretation in machine learning, we showed that two widely used algorithms - SVM and Lasso are special cases of RO, and establish their consistency via the distributional interpretation.

Boris Houska, Imperial College London (with Moritz Diehl, Oliver Stein, Paul Steuermann)

Lifting methods for generalized semi-infinite programs

In this talk we present numerical solution strategies for generalized semi-infinite optimization problems (GSIP), a class of mathematical optimization problems which occur naturally in the context of design centering problems, robust optimization problems, and many fields of engineering science. GSIPs can be regarded as bilevel optimization problems, where a parametric lower-level maximization problem has to be solved in order to check feasibility of the upper level minimization problem. In this talk we discuss three strategies to reformulate a class lower-level convex GSIPs into equivalent standard minimization problems by exploiting the concept of lower level Wolfe duality. Here, the main contribution is the discussion of the non-degeneracy of the corresponding formulations under various assumptions. Finally, these non-degenerate re-formulations of the original GSIP allow us to apply standard nonlinear optimization algorithms.

Wolfram Wiesemann, Imperial College London (with Daniel Kuhn, Berc Rustem)

Robust Markov decision processes

Markov decision processes (MDPs) are powerful tools for decision making in uncertain dynamic environments. However, the solutions of MDPs are of limited practical use due to their sensitivity to distributional model parameters, which are typically unknown and have to be estimated by the decision maker. To counter the detrimental effects of estimation errors, we consider robust MDPs that offer probabilistic guarantees in view of the unknown parameters. To this end, we assume that an observation history of the MDP is available. Based on this history, we derive a confidence region that contains the unknown parameters with a pre-specified probability $1 - \beta$. Afterwards, we determine a policy that attains the highest worst-case performance over this confidence region. By construction, this policy achieves or exceeds its worst-case performance with a confidence of at least $1 - \beta$. Our method involves the solution of tractable conic programs of moderate size.

Sparse optimization & compressed sensing

Tue.2.H 1028

Coordinate descent methods for huge-scale optimization

Organizer/Chair Peter Richtarik, University of Edinburgh · Invited Session

Peter Richtarik, University of Edinburgh (with Martin Takac)

Parallel block coordinate descent methods for huge-scale partially separable problems

In this work we show that randomized block coordinate descent methods can be accelerated by parallelization when applied to the problem of minimizing the sum of a partially block separable smooth convex function and a simple block separable convex function. We give a generic algorithm and several variants thereof based on the way parallelization is performed. In all cases we prove iteration complexity results, i.e., we give bounds on the number of iterations sufficient to approximately solve the problem with high probability. Our results generalize the intuitive observation that in the separable case the theoretical speedup caused

by parallelization must be equal to the number of processors. We show that the speedup increases with the number of processors and with the degree of partial separability of the smooth component of the objective function. Our analysis also works in the mode when the number of blocks being updated at each iteration is random, which allows for modelling situations with variable (busy or unreliable) number of processors. We conclude with some encouraging computational results applied to huge-scale LASSO and sparse SVM instances.

Martin Takac, University of Edinburgh (with Jakub Marecek, Peter Richtarik)

Distributed block coordinate descent method: iteration complexity and efficient hybrid implementation

In this work we propose solving huge-scale instances of regularized convex minimization problems using a distributed block coordinate descent method. We analyze the iteration complexity of the (synchronous) algorithm and show how it depends on the way the problem data is partitioned to the nodes. Several variations of the basic method are obtained based on the way updates are handled (P2P, broadcasting, asynchronicity). Finally, we report encouraging numerical results for an efficient hybrid MPI + Open MP implementation applied to LASSO and sparse support vector machine instances.

Rachael Tappenden, University of Edinburgh (with Jacek Gondzio, Peter Richtarik)

Block coordinate descent method for block-structured problems

We are concerned with very large scale convex optimization problems and an application of the Block Coordinate Descent (BCD) algorithm to determine their solution. We assume that the problems display block-structure and we show how this structure may be exploited to accelerate the BCD algorithm. At every iteration of the algorithm, the direction in each block-coordinate must be determined. We discuss the linear algebra techniques employed to accelerate this step. We also present a convergence analysis and a complexity result, which provide a linear algebra insight into the standard convex optimization techniques.

Stochastic optimization

Tue.2.MA 141

Stochastic optimization – Confidence sets, stability, robustness

Organizer/Chair Petr Lachout, Charles University in Praha · Invited Session

Silvia Vogel, TU Ilmenau

Confidence regions for level sets: Sufficient conditions

Real-life decision problems usually contain uncertainties. If a probability distribution of the uncertain quantities is available, the successful models of stochastic programming can be utilized. The probability distribution is usually obtained via estimation, and hence there is the need to judge the goodness of the solution of the 'estimated' problem. Confidence regions for constraint sets, optimal values and solution sets of optimization problems provide useful information. Recently a method has been developed which offers the possibility to derive confidence sets employing a quantified version of convergence in probability of random sets instead of the whole distribution of a suitable statistic. Uniform concentration-of-measure inequalities for approximations of the constraint and/or objective functions are crucial conditions for the approach. We will discuss several methods for the derivation of such inequalities, especially for functions which are expectations of a random function.

Petr Lachout, Charles University in Praha

Local information in stochastic optimization program

Historical observations contain information about local structure of the considered system. We can use them to build a local estimator of the probability distribution leading the system. Another local information is also available as expert suggestions and forecasts, knowledge about density smoothness, etc. We intend to describe structure of such optimization programs together with a stability discussion.

Milos Kopa, Charles University in Prague (with Jitka Dupacova)

Robustness in stochastic programs with risk and probabilistic constraints

The paper presents robustness results for stochastic programs with risk, stochastic dominance and probabilistic constraints. Due to their frequently observed lack of convexity and/or smoothness, these programs are rather demanding both from the computational and robustness point of view. Under suitable conditions on the structure of the problem, we exploit the contamination technique to analyze the resistance of optimal value with respect to the alternative probability distribution. We apply this approach to mean-risk models and portfolio efficiency testing with respect to stochastic dominance criteria.

Stochastic optimization

Tue.2.MA 144

Topics in stochastic programming

Organizer/Chair Guzin Bayraksan, University of Arizona · Invited Session

Johannes Royset, Naval Postgraduate School (with Roger Wets)

Nonparametric estimation using exponential epi-splines

We develop a flexible framework for nonparametric estimation of probability density functions that systematically incorporates soft information from human sources and experiences. The framework results in infinite dimensional stochastic optimization problems that are replaced by finite dimensional approximations based on exponential epi-splines. We show consistency of approximations as the order of the epi-spline grows as well as the sample size tends to infinity. We also discuss asymptotics and the implementation of soft information that dramatically improves the quality of the estimates.

David Morton, The University of Texas at Austin (with John Hasenbein, Jinho Lee)

Rapidly detecting an anomaly spreading stochastically on a network

We consider an anomaly that spreads according to stochastic dynamics on a network. Subject to a budget constraint, we install sensors on nodes of the network to maximize the probability we detect the anomaly by a time threshold. Using a Monte Carlo approximation of a stochastic integer program, we solve large-scale problem instances using data from a cellphone service provider.

Raghu Pasupathy, Virginia Tech (with Soumyadip Ghosh)

On interior-point based retrospective approximation methods for solving two-stage stochastic linear programs

We consider two-stage stochastic linear programs, the foundational formulation for optimization under uncertainty. The most general form lets the underlying distributions have infinite support. Approximate solutions to such problems are obtained by the *sample average approximation* approach of solving the program for a finite sample from the distribution. A recent thread of literature focuses on using interior point methods to efficiently solve two-stage programs for finite support random variables. Our contribution generalizes this formulation by incorporating it into a *retrospective approximation* (RA) framework. What results is an implementable interior-point solution paradigm that can be used to solve general two-stage stochastic linear programs to a desirable accuracy. After discussing some basic convergence properties, we characterize the complexity of the algorithm, leading to guidance on the optimal choice of the RA framework's parameters as a function of the effort expended in solving the sub-problems and the effort expended in solving the master problem.

Stochastic optimization

Tue.2.MA 376

Computational aspects of stochastic integer programming for large-scale and/or real-world problems

Organizer/Chair Jörg Rambau, Universität Bayreuth · Invited Session

Jonas Schweiger, Zuse Institute Berlin

Multi-scenario topology optimization in gas networks

With the deregulations in the gas markets, the requirements on the network change rapidly and demand more flexibility from the network operators. Gas network operators therefore have to invest into their network infrastructure. As these investments are very cost-intensive and long-living, network extensions should not only focus on one bottleneck scenario, but should increase the flexibility to fulfill different demand scenarios.

In this presentation, we formulate a model for the network extension problem for multiple demand scenarios. That is, we search cost-optimal network extensions such that a variety of demand scenarios can be realized in the extended network. We propose a decomposition along the scenarios and solve the problem by a branch&bound-algorithm which uses the single-scenario problem as subproblem. Since the single-scenario problem itself is a challenging mixed-integer non-convex optimization problem, we solve them to global optimality only in the leaf nodes of our branch&bound-tree, but still use valid bounds and solutions in every node of the tree.

Miriam Kießling, Universität Bayreuth (with Sascha Kurz, Jörg Rambau)

ISPO – Integrated size and price optimization for a fashion discounter with many branches

We present the integrated size and price optimization problem (ISPO) for a fashion discounter with many branches. Branches are supplied by pre-packaged bundles consisting of items of different size and number – so-called lot-types. Our goal is to find a revenue-maximizing supply strategy. Based on a two-stage stochastic programming model

including the effect of markdowns as recourse, we developed an exact branch-and-bound algorithm where dual bounds are obtained by combinatorial bounds combined with LP-relaxations. For practical purposes we developed a production-compliant heuristic, the so-called ping-pong-heuristic, that uses the special structure of the problem by alternately solving price and size optimization. In all tested cases we obtain very small optimality gaps (< 0.03 %). In a field study we show that a distribution of supply over branches and sizes based on ISPO solutions leads to better results in terms of realized return than a one-stage optimization of the distribution ignoring the possibility of optimal pricing.

Konrad Schade, Volkswagen AG

The stochastic guaranteed service model

Order policies are crucial in supply chain management. This talk is about the stochastic-guaranteed-service-model (SGSM) and its use in finding cost-minimizing orderpoints within a multi-echelon inventory system applying the (s, S) -strategy. The guaranteed-service-model (GSM) provides such orderpoints under the assumption of reliable internal lead times and bounded total demand. We introduce the SGSM – a two-stage stochastic MILP – that extends the GSM and enables recourse actions. To solve the SGSM we generate scenarios with the sample average approximation. We reduce the number of scenarios considered in the solution algorithm through a scenario reduction technique, the fast forward selection. We get the best results using an asymmetric distance based on the objective function of the SGSM we want to solve between the scenarios. Simulation based on real world data of a large german car manufacturer show the improvement of applying the SGSM. The results are compared to the GSM, a decentral solution without optimization within the network and another stochastic optimization method.

Telecommunications & networks

Tue.2.H 3002

Tree problems

Organizer/Chair Ivana Ljubic, University of Vienna · Invited Session

Bernd Zey, TU Dortmund (with Immanuel Bomze, Markus Chimani, Michael Jünger, Ivana Ljubic, Petra Mutzel)

The stochastic Steiner tree problem: Models and solution strategies

We consider the Steiner tree problem under a two-stage stochastic model with fixed recourse and finitely many scenarios. Thereby, edges are bought in the first stage when only probabilistic information on future edge costs and the set of terminals is known. In the second stage, one scenario is realized and additional edges are purchased to connect the now known set of terminals. The goal is to buy profitable edges in the first stage such that the overall expected costs are minimized, i.e., the sum of the first and expected second stage costs.

We discuss the strength of undirected, semi-directed, and directed cut-set based integer programming models with binary first and second stage variables. To solve this NP-hard problem to optimality, we suggest a branch-and-cut approach based on Benders decomposition and the derived Integer-L-shaped algorithm. By a simple modification of the optimal dual solution of the subproblems we show how to improve the generated optimality Cuts which reduce the running time significantly. In our experiments we compare the extended formulation and the decomposition of the different models computationally.

Pedro Moura, CIO - University of Lisbon (with Luis Gouveia, Amaro Sousa)

Generalized degree constraints arising in wireless networks problems

We describe a minimum spanning tree problem with generalized degree constraints which arises in the design of wireless networks. In these networks, each link is implemented through a point-to-point wireless transmission system composed by a transmitter/receiver antenna and a signal processing unit at each side of the link. Each system works on different frequency channels chosen from a limited set of available channels. Possible overlapping may occur in a node, i.e., part of the transmitted signal on one channel is added as interference on the received signal on another channel. Due to propagation effects, the signal strength on the receiver side decreases as the distance to the transmitter side increases. Therefore, the maximum distance between antennas that allow the link to work properly, depends on the amount of interference introduced by all the frequency channels used on its end nodes. We consider different types of links that may be installed between two nodes depending on the distance between them and their degrees. We propose three models and compare the linear programming relaxations. We also test these models against a set of instances with up to 100 nodes.

Subramanian Raghavan, University of Maryland (with Eduardo Alvarez Miranda, Ivana Ljubic, Paolo Toth)

Recoverable robust two level network design

In this problem one of two available technologies can be installed on each edge and all customers of the network need to be served by at

least the lower level (secondary) technology. We are confronted with uncertainty regarding the set of primary customers, i.e., the set of nodes that need to be served by the higher level (primary) technology. A set of discrete scenarios associated to the possible realizations of primary customers is available. The network is built in two stages. One may decide to install the primary technology on some of the edges in the first stage, or one can wait to see which scenario will be realized, in which case, edges with the installed secondary technology may be upgraded to primary technology, but at higher recovery cost. The goal is to build a spanning tree in the first stage that serves all customers by at least the lower level technology, and minimizes the first stage installation cost plus the worst-case cost needed to upgrade the edges of that tree, so that the primary customers of each scenario can be served using the primary technology. We study the complexity of the problem on trees and provide MIP models and a branch-and-cut approach.

Variational analysis

Tue.2.H 2035

Control and optimization of impulsive systems I

Organizers/Chairs Aram Arutyunov, Peoples' Friendship University of Russia; Fernando Pereira, Porto University-FEUP/Institute for Systems and Robotics Porto · Invited Session

Dmitry Karamzin, Computing Centre RAS (with Aram Arutyunov, Fernando Pereira)

Existence theorems and Pontryagin's Maximum Principle for impulsive control problems

This report addresses existence theorems and Pontryagin's Maximum Principle for constrained impulsive control problems with a new concept of impulsive control. This concept enables extra controls (conventional bounded controls) which act on the discontinuities of the impulsive system. Such type of impulsive controls can be encountered in different engineering applications in which, for example, it might be necessary to take into account rapid variations in mass distribution of a mechanical system during the short time when the impulse is being applied. There are, of course, many other applications. We provide a detailed example showing how these controls could be useful.

Geraldo Silva, UNESP - Universidade Estadual Paulista (with Valeriano Oliveira)

Optimal impulsive control problems under uncertainty

This work provides an approach to treat optimal impulsive control problems with uncertain parameters and provide necessary conditions in the form of a maximum principle. The uncertain parameter is a vector in the objective function and is chosen from a set A which is taken to be a compact metric space. The necessary conditions obtained here is a generalization of the minimax maximum principle derived earlier for non impulsive optimal control problems [Vinter04].

Valeriano de Oliveira, State University of São Paulo (with Geraldo Silva)

An Invexity Type Condition on Impulsive Optimal Control Systems

It is well-known in optimal control theory that the maximum principle furnishes necessary optimality conditions for an admissible process to be an optimal one. It is also well-known that if a process satisfies the maximum principle in a problem with convex data, the maximum principle turns to be likewise a sufficient condition. We here define an invexity type condition for impulsive optimal control problems. We then show that this is a sufficient optimality condition. Our definition was motivated by the one given by [Martin85], where a generalized invexity notion, called KT-invexity is introduced for mathematical programming problems. Martin took into account the KT conditions when he designed the KT-invexity. In this work we do the same, but with the Maximum Principle for optimal control problems in the impulsive setting.

Variational analysis

Tue.2.H 2051

Regularity and sensitivity in multicriteria optimization

Organizer/Chair Constantin Zalinescu, University Alexandru Ioan Cuza Iasi · Invited Session

Marius Durea, Al. I. Cuza University of Iasi

Metric regularity and Fermat rules in set-valued optimization

We discuss several techniques for getting Fermat rules for set-valued unconstrained optimization. Among these techniques which are, in a sense, equivalent, we focus on a method based on the incompatibility between the metric regularity (or openness at linear rate) of set-valued maps and the optimality in the sense of Pareto. We describe technically how the well known contradiction between regularity and optimality could be successfully transposed into a set-valued context and then we identify several metric regularity/ openness results which serve our final purpose. We observe that in order to get good Fermat rules (i.e. under mild conditions) one should have to derive new specific

openness results which could be of interest for its own. Several possibilities in this direction are investigated, each one giving a specific final outcome. Moreover, some applications to vector equilibrium problems are envisaged. Since, in general, our method allows to firstly deduce approximate Fermat rules for set-valued optimization problems in the setting of general Banach spaces, through this presentation we will have the possibility to underline several regularity and stability issues.

Radu Strugariu, Gh. Asachi Technical University of Iasi, Romania

Metric regularity and subregularity of set-valued mappings with applications to vector optimization

This presentation is devoted to the investigation of different types of regularity for set-valued mappings, with applications to the study of the well-posedness of the solution mappings associated to parametric variational systems. We present some general theorems concerning chain rules for linear openness of multifunctions and we obtain, as particular cases, some classical and also some new results in this field of research, including the celebrated Lyusternik Graves Theorem. Also, we classify the at-point regularities (or subregularities) of set-valued mappings into two categories and then we analyze their relationship. After that, we show how to use the subregularity properties to deduce implicit theorems for set-valued maps. Finally, we present some applications to the study of multicriteria optimization problems.

Constantin Zalinescu, University Alexandru Ioan Cuza Iasi

Variational principles for multifunctions and applications

The usefulness of the Ekeland Variational Principle (EVP) is well known in Nonlinear Analysis. In the last thirty years many variants for vector-valued functions were established. In our talk we present several versions of the EVP in which the usual (minorized) function as well as the distance function are replaced by multifunctions. Then we present an application to error bounds.

Approximation & online algorithms

Tue.3.H 3010

Travelling salesman problem II

Organizers/Chairs Sylvia Boyd, University of Ottawa; David Shmoys, Cornell University · Invited Session

Mohit Singh, Microsoft Research (with Shayan Oveis Gharan, Amin Saberi)

A randomized rounding approach to the traveling salesman problem

For some positive constant ϵ , we give a $(\frac{3}{2} - \epsilon)$ -approximation algorithm for the following problem: given a graph $G = (V, E)$, find the shortest tour that visits every vertex at least once. This is a special case of the metric traveling salesman problem when the underlying metric is defined by shortest path distances in G . The result improves on the $\frac{3}{2}$ -approximation algorithm due to Christofides for this special case. Similar to Christofides, our algorithm finds a spanning tree whose cost is upper bounded by the optimum, it finds the minimum cost Eulerian augmentation of that tree. The main difference is in the selection of the spanning tree. Except in certain cases where the solution of LP is nearly integral, we select the spanning tree randomly by sampling from a maximum entropy distribution defined by the linear programming relaxation. Despite the simplicity of the algorithm, the analysis builds on a variety of ideas such as properties of strongly Rayleigh measures from probability theory, graph theoretical results on the structure of near minimum cuts, and the integrality of the T-join polytope from polyhedral theory.

Tobias Mömke, KTH Royal Institute of Technology (with Ola Svensson)

Approximating graphic TSP by matchings

We present a framework for approximating the metric TSP based on a novel use of matchings. Traditionally, matchings have been used to add edges in order to make a given graph Eulerian, whereas our approach also allows for the removal of certain edges leading to a decreased cost. For the TSP on graphic metrics (graph-TSP), the approach yields a 1.461-approximation algorithm with respect to the Held-Karp lower bound. For graph-TSP restricted to a class of graphs that contains degree three bounded and claw-free graphs, we show that the integrality gap of the Held-Karp relaxation matches the conjectured ratio $\frac{4}{3}$.

Marcin Mucha, University of Warsaw

13/9-approximation for graphic TSP

The Travelling Salesman Problem (TSP) is one of the most fundamental and most studied problems in approximation algorithms. For more than 30 years, the best algorithm known for general metrics has been Christofides's algorithm with approximation factor of $\frac{3}{2}$, even though the so-called Held-Karp LP relaxation of the problem is conjectured to have the integrality gap of only $\frac{4}{3}$.

In the so-called *graphic* version of TSP we assume that (V, d) is a shortest path metric of an unweighted, undirected graph. The reason why this special case is interesting is that it seems to include the diffi-

cult inputs of TSP. Not only is it APX-hard, but also the standard examples showing that the Held-Karp relaxation has a gap of at least $\frac{4}{3}$ are in fact graphic.

Very recently, significant progress has been made for the graphic TSP, first by Oveis Gharan et al., and then by Mömke and Svensson. In this paper, we provide an improved analysis of the approach used by the latter yielding a bound of $\frac{13}{9}$ on the approximation factor. We also provide improved bounds for the related graphic TSP path problem.

Combinatorial optimization

Tue.3.H 3004

Extended formulations in discrete optimization I

Organizers/Chairs Samuel Fiorini, Université libre de Bruxelles (ULB); Gautier Stauffer, University Bordeaux 1 – INRIA · Invited Session

Sebastian Pokutta, University of Erlangen-Nürnberg (with Ronald de Wolf, Samuel Fiorini, Serge Massar, Hans-Raj Tiwary)

On linear programming formulations of the TSP polytope

We solve a 20-year old problem posed by M. Yannakakis and prove that there exists no polynomial-size linear program (LP) whose associated polytope projects to the traveling salesman polytope, even if the LP is not required to be symmetric. Moreover, we prove that this holds also for the maximum cut problem and the stable set problem. These results follow from a new connection that we make between one-way quantum communication protocols and semidefinite programming reformulations of LPs.

Thomas Rothvoss, M.I.T.

Some 0/1 polytopes need exponential size extended formulations

We prove that there are 0/1 polytopes $P \subseteq \mathbb{R}^n$ that do not admit a compact LP formulation. More precisely we show that for every n there is a set $X \subseteq \{0, 1\}^n$ such that $\text{conv}(X)$ must have extension complexity at least $2^{n/2 \cdot (1 - o(1))}$. In other words, every polyhedron Q that can be linearly projected on $\text{conv}(X)$ must have exponentially many facets.

In fact, the same result also applies if $\text{conv}(X)$ is restricted to be a matroid polytope.

The paper is available under: <http://arxiv.org/abs/1105.0036>

Roland Grappe, LIPN - équipe AOC (with Yuri Faenza, Samuel Fiorini, Tiwary Hans Raj)

Extended formulations, non-negative factorizations, and randomized communication protocols

We show that the binary logarithm of the non-negative rank of a non-negative matrix is, up to small constants, equal to the minimum complexity of a randomized communication protocol computing the matrix in expectation.

We use this connection to prove new conditional lower bounds on the sizes of extended formulations, in particular, for perfect matching polytopes.

Combinatorial optimization

Tue.3.H 3005

Matroid parity

Organizer/Chair Tamás Király, Eötvös University, Budapest · Invited Session

Ho Yee Cheung, University of Southern California (with Lap Chi Lau, Kai Man Leung)

Algebraic algorithms for linear matroid parity problems

We present faster and simpler algebraic algorithms for the linear matroid parity problem and its applications. For the linear matroid parity problem, we obtain a simple randomized algorithm with running time $O(mr^{\omega-1})$, which improves the $O(mr^\omega)$ -time algorithm by Gabow and Stallmann. We also present a very simple alternative algorithm with running time $O(mr^2)$. We further improve the algebraic algorithms for some specific graph problems of interest. We present faster randomized algorithms for the Mader's disjoint \mathcal{S} -path problem and the graphic matroid parity problem.

The techniques are based on the algebraic algorithmic framework developed by Mucha, Sankowski and Harvey. While linear matroid parity and Mader's disjoint \mathcal{S} -path are challenging generalizations for the design of combinatorial algorithms, our results show that both the algebraic algorithms for linear matroid intersection and graph matching can be extended nicely to more general settings. All algorithms are still faster than the existing algorithms even if fast matrix multiplications are not used. These provide simple algorithms that can be easily implemented.

Satoru Iwata, Kyoto University

Weighted linear matroid parity

The matroid parity problem was introduced as a common generalization of matching and matroid intersection problems. In the worst

case, it requires an exponential number of independence oracle calls. Nevertheless, the problem is solvable if the matroid in question is represented by a matrix. This is a result of Lovász (1980), who discovered a min-max theorem as well as a polynomial time algorithm. Subsequently, more efficient algorithms have been developed for this linear matroid parity problem.

This talk presents a combinatorial, deterministic, strongly polynomial algorithm for its weighted version. The algorithm builds on a polynomial matrix formulation of the problem using Pfaffian and an augmenting path algorithm for the unweighted version by Gabow and Stallmann (1986).

Independently of this work, Gyula Pap has obtained the same result based on a different approach.

Gyula Pap, Eötvös University

Weighted linear matroid parity - A primal-dual approach

In the matroid parity problem we are given a matroid partitioned into pairs – subsets of cardinality 2. A set of pairs is called a matching if their union is an independent set. The (unweighted) matroid parity problem is to maximize the cardinality of a matching. This problem is solvable in polynomial time for linear matroids by Lovász' famous result – a generalization of graphical matching, and (linear) matroid intersection, both of which are solvable also in the weighted version. Thus one suspects the natural weighted version of linear matroid matching to also be tractable: consider a linear matroid whose elements are assigned weights, and partitioned into pairs – find a matching whose total weight is maximal. A solution to this problem would generalize both of Edmonds' algorithms, for matching, and for (linear) matroid intersection as well. In this talk a primal-dual algorithm is presented to solve weighted linear matroid matching in strongly polynomial time. A different solution to this problem has been found independently by Iwata.

Combinatorial optimization

Tue.3.H 3008

Combinatorics and geometry of linear optimization II

Organizers/Chairs Jesus De Loera, University of California, Davis; Antoine Deza, McMaster University · Invited Session

Gabor Pataki, UNC Chapel Hill

Bad semidefinite programs: They all look the same

In the duality theory of semidefinite programming (SDP), unlike in LP, "pathological" phenomena occur: nonattainment of the optimal value, and positive duality gaps between the primal and dual problems.

This research was motivated by the curious similarity of pathological SDP instances appearing in the literature. We find an exact characterization of semidefinite systems, which are badly behaved from the viewpoint of duality, i.e., show that "all bad SDPs look the same". We also prove an excluded minor type result: all badly behaved semidefinite systems can be reduced (in a well defined sense) to a minimal such system with just one variable, and two by two matrices. Our characterizations imply that recognizing badly behaved semidefinite systems is in $\text{NP} \cap \text{coNP}$ in the real number model of computing.

The main results follow from a fairly general characterization of badly behaved conic linear systems, and hinge on a previous theorem on the closedness of the linear image of a closed convex cone. We show characterizations of badly behaved second order, and other conic systems as well.

Tamon Stephen, Simon Fraser University (with Francisco Santos, Hugh Thomas)

The width of 4-prismatoids

Santos' construction of a counterexample to the Hirsch conjecture highlights a particular 5-dimensional "prismatoid" polytope. We use the Euler characteristic to prove that there is no analogous 4-dimensional prismatoid.

David Bremner, University of New Brunswick (with Yan Cui)

Minimum norm points on the boundary of convex polytopes

Given two sets of vectors in $P, Q \subseteq \mathbb{R}^d$ the maximum margin hyperplane is defined by the solution to the following

$$\text{margin}(P, Q) = \sup_{w \in \text{bd}\mathbb{B}^*} \inf_{p \in P, q \in Q} \langle w, p - q \rangle$$

where \mathbb{B} is the relevant unit ball.

In the case where $\text{margin}(P, Q) \geq 0$, (the separable case), this problem is dual to finding the minimum norm point in the Minkowski sum $P \oplus Q$ of $\text{conv}P$ and $\text{conv} - Q$ and can thus be solved efficiently.

When $\mathbf{0} \in \text{int}(P \oplus Q)$, margin is dual to finding the smallest translation that makes the two sets separable. It turns out this is defined by the minimum norm point on the boundary of $P \oplus Q$. In this case the feasible is only piecewise convex, and the problem is NP-hard.

In this talk I will discuss experimental results from two approaches to the non-separable case. The first approach solves one convex min-

imization per facet of $P \ominus Q$. The second approach (applicable only to polytopal norms) solves one LP per vertex of the unit ball \mathbb{B} .

Combinatorial optimization

Tue.3.H 3012

LP relaxations

Chair Dorit Hochbaum, UC Berkeley

Maria Teresa Godinho, IPBEja & CIO (with Luís Gouveia, Pierre Pesneau)

On a time-dependent formulation for the travelling salesman problem

In the past, several papers have produced a classification of formulations for the ATSP, in terms of the associated linear programming relaxations. Among others, we may consider the papers by Gouveia and Voss (1995), Langevin et al (1990), Gouveia and Pires (1999), Orman and Williams (2007) and Oncan et al (2009). These papers fall among two classes. Either they produce new results between formulations known from the literature, or they use the fact that new formulations are also being presented in the paper in order to upgrade a classification already known from the literature. Our talk falls in the second category in the sense that we present an updated classification of formulations for the asymmetric travelling salesman problem (ATSP) where we contextualize, in terms of the ATSP, a new time-dependent formulation presented in Godinho et al (2010). The main feature of this formulation is that it uses, for each node, a stronger subproblem, namely a n -circuit subproblem with the additional constraint that the corresponding node is not repeated in the circuit.

Dorit Hochbaum, UC Berkeley

Flow-based algorithms that solve clustering problems related to graph expander, normalized cut and conductance better than the spectral method

We address challenging problems in clustering, partitioning and imaging including the normalized cut problem, graph expander, Cheeger constant problem and conductance problem. These have traditionally been solved using the "spectral technique". These problems are formulated here as a quadratic ratio (Rayleigh) with discrete constraints and a single sum constraint. The spectral method solves a relaxation that omits the discreteness constraints. A new relaxation, that omits the sum constraint, is shown to be solvable in strongly polynomial time. It is shown, via an experimental study, that the bipartition achieved by the combinatorial algorithm often improve dramatically in terms of the objective value of the respective NP-hard problem, as well as in terms of the visual quality of the segmentation, compared to the spectral method in image segmentation and image denoising instances.

Yong-Hong Kuo, The Chinese University of Hong Kong (with Janny Leung)

On the mixed set covering, partitioning and packing problem

Set covering, set partitioning and set packing problems have already been studied for more than 40 years. However, researchers usually consider the problems individually and very few literatures have mentioned the mixed set covering, partitioning and packing problem, where the three kinds of constraints are present simultaneously in the formulation. The problems with such kind of structures play an important role in the real-life applications, e.g., staff scheduling problems. In this talk, we will discuss the polyhedral structure of the problem and present a way, which we call "implicit edges generation" approach, to further tighten the feasible region and, as a result, makes the LP optimal closer to the IP optimal. We will also present some classes of facet-defining inequalities produced by this approach. Computational results show that, using our proposed methodology, a tighter formulation can be obtained and, consequently significant reductions of computational efforts are made.

Combinatorial optimization

Tue.3.H 3013

Combinatorial optimization and equilibria for flows over time

Organizers/Chairs Neil Olver, MIT; Jose Correa, Universidad de Chile - Invited Session

Lisa Fleischer, Dartmouth College (with Elliot Anshelevich, Umang Bhaskar)

Competitive strategies for routing flow over time

The study of routing games is motivated by the desire to understand the impact of many individual users' decisions on network efficiency. To do this, prior work uses a simplified model of network flow where all flow exists simultaneously, and users route flow to either minimize their maximum delay or their total delay. Both of these measures are surrogates for measuring how long it takes to get all of your traffic through the network over time.

Instead of using these surrogates, we attempt a more direct study of how competition among users effects network efficiency by examining routing games in a flow-over-time model. We show that the network owner can reduce available capacity so that the competitive equilibrium in the reduced network is no worse than a small constant times the optimal solution in the original network using two natural measures of optimum: the time by which all flow reaches the destination, and the average amount of time it takes flow to reach the destination.

Omar Larre, Universidad de Chile (with Roberto Cominetti, José Correa)

Existence and uniqueness of equilibria for flows over time

Network flows that vary over time arise naturally when modeling rapidly evolving systems such as the Internet. In this paper, we continue the study of equilibria for flows over time in the single-source single-sink deterministic queuing model proposed by Koch and Skutella. We give a constructive proof for the existence and uniqueness of equilibria for the case of a piecewise constant inflow rate, through a detailed analysis of the static flows obtained as derivatives of a dynamic equilibrium.

Ronald Koch, TU Berlin (with Ebrahim Nasrabadi, Martin Skutella)

Continuous and discrete flows over time

Network flows over time form a fascinating area of research. They model the temporal dynamics of network flow problems occurring in a wide variety of applications. Research in this area has been pursued in two different and mainly independent directions with respect to time modeling: discrete and continuous time models.

In this talk we deploy measure theory in order to introduce a general model of network flows over time combining both discrete and continuous aspects into a single model. Here, the flow on each arc is modeled as a Borel measure on the real line (time axis) which assigns to each suitable subset a real value, interpreted as the amount of flow entering the arc over the subset. We motivate the usage of measures as a quite natural tool for modeling flow distributions over time. In particular, we show how static flow theory can be adopted to obtain corresponding results for this general flow over time model.

Combinatorial optimization

Tue.3.H 3021

New insights for old problems

Organizer/Chair Andreas S. Schulz, MIT - Invited Session

Gautier Stauffer, University Bordeaux 1 - INRIA (with Jean-Philippe Gayon, Guillaume Massonnet, Christophe Rapine)

A simple and fast 2-approximation algorithm for the one-warehouse multi-retailer problem

In the One-Warehouse Multi-Retailer (OWMR) problem, we want to optimize the distribution of a single item over a network composed of one warehouse and N different retailers over a discrete finite planning horizon of T periods. Each retailer is facing deterministic demands that have to be fulfilled on time by ordering those units from the warehouse, which in turn have to be ordered from an external supplier of infinite capacity. The objective of the OWMR problem is to find a planning for the orders at each location (i.e., period and quantity) that minimizes the sum of the fixed ordering costs and holding costs in the system. The cost of ordering is fixed, independent of the number of products, while a per-unit holding cost is paid at each location to keep an item in stock. This problem is NP-hard but efficient 1.8- and 2-approximation algorithms have been proposed in the literature. The corresponding algorithms are based on sophisticated LP techniques (randomized rounding and primal dual). In this talk we present a simple 2-approximation algorithm that is purely combinatorial and that can be implemented to run in linear time.

Danny Segev, University of Haifa

An approximate dynamic-programming approach to the joint replenishment problem

In this talk, I will present a high-level view of a very recent approach for ϵ -approximating the joint replenishment problem, with stationary demands and holding costs. Based on synthesizing ideas such as commodity aggregation, approximate dynamic programming, and a few guessing tricks, it turns out that one can attain any required degree of accuracy in time $O((nT)^{O(\log \log T)})$, where n denotes the number of given commodities, and T stands for the number of time periods.

Andreas S. Schulz, MIT (with Claudio Telha Cornejo)

The joint replenishment problem and the problem of clustering frequency-constrained maintenance jobs are integer-factorization hard

We present a new connection between certain sequencing problems involving the coordination of activities and the problem of integer factorization. We use this connection to derive hardness results for three well-known problems in operations management whose computational complexity has been open for more than two decades:

- The joint replenishment problem with general integer policies.
- The joint replenishment problem with correction factor.
- The problem of finding an optimal clustering of frequency-constrained maintenance jobs.

Our hardness results imply that no polynomial-time algorithm exists for either problem, unless integer factorization is solvable in polynomial time.

Complementarity & variational inequalities

Tue.3.MA 041

Differential variational inequalities

Organizer/Chair Mihai Anitescu, Argonne National Laboratory · Invited Session

Lei Wang, Argonne National Lab (with Shirang Abhyankar, Mihai Anitescu, Jungho Lee, Lois McInnes, Todd Munson, Barry Smith)

Large-scale differential variational inequalities for phase-field modeling

Recent progress on the development of scalable differential variational inequality multigrid-based solvers for the phase-field approach to mesoscale materials modeling is described. We have developed a reduced space method, augmented reduced space method, and semismooth method for variational inequalities in PETSc, leveraging experience by the optimization community in TAO. A geometric multigrid solver in PETSc is used to solve the resulting linear systems. We present strong and weak scaling results for 2D coupled Allen-Cahn/Cahn-Hilliard systems.

Michael Hintermüller, Humboldt-Universität zu Berlin (with Thomas Surowiec)

A bundle-free implicit programming approach for MPECs in function space via smoothing

Using a standard first-order optimality condition for nonsmooth optimization problems, a general framework for a descent method is developed. This setting is applied to a typical class of mathematical programs with equilibrium constraints in function space from which a new algorithm is derived. Global convergence of the algorithm is demonstrated in function space and the results are then illustrated by numerical experiments.

Mohammad Hassan Farshbaf-Shaker, Universität Regensburg (with Claudia Hecht)

Optimal control of vector-valued elastic Allen-Cahn variational inequalities

A vector-valued elastic Allen-Cahn-MPEC problem is considered and a penalization technique is applied to show the existence of an optimal control. We show that the stationary points of the penalized problems converge to some stationary points of the limit problem, which however are weaker than C-stationarity conditions.

Complementarity & variational inequalities

Tue.3.MA 313

MPECs in function space II

Organizers/Chairs Christian Meyer, TU Dortmund; Michael Hintermüller, Humboldt-Universität zu Berlin · Invited Session

Stanislaw Migorski, Jagiellonian University, Faculty of Mathematics and Computer Science

An optimal control problem for a system of elliptic hemivariational inequalities

In this paper we deal with a system of two hemivariational inequalities which is a variational formulation of a boundary value problem for two coupled elliptic partial differential equations. The boundary conditions in the problem are described by the Clarke subdifferential multivalued and nonmonotone laws. First, we provide the results on existence and uniqueness of a weak solution to the system. Then we consider an optimal control problem for the system, we prove the continuous dependence of a solution on the control variable, and establish the existence of optimal solutions. Finally, we illustrate the applicability of the results in a study of a mathematical model which describes the static frictional contact problem between a piezoelectric body and a foundation.

Juan Carlos De los Reyes, Escuela Politécnica Nacional Quito

Optimality conditions for control problems of variational inequalities of the second kind

In this talk we discuss optimality conditions for control problems governed by a class of variational inequalities of the second kind. Applications include the optimal control of Bingham viscoplastic materials and simplified friction problems. If the problem is posed in \mathbb{R}^n an optimality system has been derived by J. Outrata [2000]. When considered in function spaces, however, the problem presents additional difficulties.

We propose an alternative approximation approach based on a Huber type regularization of the governing variational inequality. By using a family of regularized optimization problems and performing an

asymptotic analysis, an optimality system for the original optimal control problem (including complementarity relations between the variables involved) is obtained.

We discuss on the gap between the function space optimality system and the finite-dimensional one, and explore sufficient conditions in order to close the gap.

Gerd Wachsmuth, TU Chemnitz (with Roland Herzog, Christian Meyer)

Optimal control of quasistatic plasticity

An optimal control problem is considered for the variational inequality representing the stress-based (dual) formulation of quasistatic elastoplasticity. The linear kinematic hardening model and the von Mises yield condition are used. By showing that the VI can be written as an evolutionary variational inequality, we obtain the continuity of the forward operator. This is the key step to prove the existence of minimizers.

In order to derive necessary optimality conditions, a family of time discretized and regularized optimal control problems is analyzed. By passing to the limit in the optimality conditions for the regularized problems, necessary optimality conditions of weakly stationarity type are obtained.

We present a solution method which builds upon the optimality system of the time discrete and regularized problem. Numerical results which illustrates the possibility of controlling the springback effect.

Conic programming

Tue.3.H 2036

First-derivative and interior methods in convex optimization

Organizer/Chair Stephen Vavasis, University of Waterloo · Invited Session

Miguel Anjos, École Polytechnique de Montreal (with Alexander Engau)

Convergence and polynomiality of a primal-dual interior-point algorithm for linear programming with selective addition of inequalities

We present the convergence proof and complexity analysis for an interior-point framework that solves linear programming problems by dynamically selecting and adding inequalities. First, we formulate a new primal-dual interior-point algorithm for solving linear programs in nonstandard form with equality and inequality constraints. The algorithm uses a primal-dual path-following predictor-corrector short-step interior-point method that starts with a reduced problem without any inequalities and selectively adds a given inequality only if it becomes active on the way to optimality. Second, we prove convergence of this algorithm to an optimal solution at which all inequalities are satisfied regardless of whether they have been added by the algorithm or not. We thus provide a theoretical foundation for similar schemes already used in practice. We also establish conditions under which the complexity of the algorithm is polynomial in the problem dimension.

Olivier Devolder, Université Catholique de Louvain (UCL) (with François Glineur, Yurii Nesterov)

Intermediate gradient methods for smooth convex optimization problems with inexact oracle

Between the slow but robust gradient method and the fast but sensitive to errors fast gradient method, we develop new intermediate gradient methods for smooth convex optimization problems. We show, theoretically and on numerical experiments, that these new intermediate first-order methods can be used in order to accelerate the minimization of a smooth convex function when only inexact first-order information is available.

Jose Herskovits, COPPE / Federal University of Rio de Janeiro (with Miguel Aroztegui, Jean Roche)

A feasible direction interior point algorithm for nonlinear convex semidefinite programming

The present method employs basic ideas of FDIPA [1], the Feasible Direction Interior Point Algorithm for nonlinear optimization. It generates a descent sequence of points at the interior of the feasible set, defined by the semidefinite constraints. The algorithm performs Newton-like iterations to solve the first order Karush-Kuhn-Tucker optimality conditions. At each iteration, two linear systems with the same coefficient matrix must be solved. The first one generates a descent direction. In the second linear system, a precisely defined perturbation in the left hand side is done and, as a consequence, a descent feasible direction is obtained. An inexact line search is then performed to ensure that the new iterate is interior and the objective is lower. A proof of global convergence of is presented. Some numerical are described. We also present the results with structural topology optimization problems employing a mathematical model based on semidefinite programming. The results suggest efficiency and high robustness of the proposed method.

[1] Herskovits J. A Feasible Directions Interior Point Technique For Nonlinear Optimization. JOTA, v. 99, n. 1, p. 121–146, 1998.

Conic programming

Tue.3.H 2038

Conic and convex programming in statistics and signal processing I

Organizer/Chair Parikshit Shah, University of Wisconsin · Invited Session

Bamdev Mishra, University of Liege (with Rodolphe Sepulchre)

Fixed-rank matrix factorizations and the design of invariant optimization algorithms

Optimizing over low-rank matrices is a fundamental problem arising in many modern machine learning applications. One way of handling the rank constraint is by fixing the rank a priori resulting in a fixed-rank factorization model. We study the underlying geometries of several well-known fixed-rank matrix factorizations and then exploit the Riemannian framework of the search space in the design of gradient descent and trust-region algorithms.

We focus on the invariance properties of certain metrics. Specifically, we seek to develop algorithms that can be made invariant to linear transformation of the data space. We show that different Riemannian geometries lead to different invariance properties and we provide numerical evidence to support the effect of invariance properties on the algorithm performance.

We make connections with existing algorithms and discuss relative usefulness of the proposed framework. Numerical experiments suggest that the proposed algorithms compete with the state-of-the-art and that manifold optimization offers an effective and versatile framework for the design of machine learning algorithms that learn a fixed-rank matrix.

Lieven Vandenberghe, UCLA (with Martin Andersen)

Multifrontal barrier computations for sparse matrix cones

We discuss conic optimization problems involving two types of convex matrix cones: the cone of positive semidefinite matrices with a given chordal sparsity pattern, and its dual cone, the cone of matrices with the same sparsity that have a positive semidefinite completion. We describe efficient algorithms for evaluating the values, gradients, and Hessians of the logarithmic barrier functions for the two types of cones. The algorithms are based on techniques used in multifrontal and supernodal sparse Cholesky factorization methods. The results will be illustrated with applications in covariance selection and semidefinite programming.

Venkat Chandrasekaran, Caltech (with Michael Jordan)

Computational and sample tradeoffs via convex relaxation

In modern data analysis, one is frequently faced with statistical inference problems involving massive datasets. In this talk we discuss a computational framework based on convex relaxation in order to reduce the computational complexity of an inference procedure when one has access to increasingly larger datasets. Essentially, the statistical gains from larger datasets can be exploited to reduce the runtime of inference algorithms.

Constraint programming

Tue.3.H 3003A

Constraint programming methodology

Chair Burak Gokgur, Izmir University of Economics

Toby Walsh, NICTA and UNSW

Breaking variable and value symmetry in constraint satisfaction and optimisation problems

Factoring out the symmetry in a model is important for solving many constraint satisfaction and optimisation problems. Symmetries can act on the variables, or on the values, or on both the variables and the values in a model.

A simple but nevertheless effective method to deal with symmetry is to post static constraints which eliminate symmetric assignments. If a model has value symmetry in addition to variable symmetry, we might simply post the relevant value symmetry breaking constraints in addition to the variable symmetry breaking constraints. We consider three issues with this approach.

- Soundness: Is it safe to post together the variable and value symmetry breaking constraints?
- Completeness: Does this combination of symmetry breaking constraints eliminate all symmetry from the problem? If not, how can we eliminate all symmetry?
- Complexity: What is the complexity of breaking all variable and value symmetry? And of propagating the combination of the variable and value symmetry breaking constraints together?

Alexander Schnell, University of Vienna (with Richard Hartl)

The impact of the predefined search space on recent exact algorithms for the RCPSP

The problem of assigning starting times to a number of jobs subject to resource and precedence constraints is called the resource-constrained project scheduling problem (RCPSP). This presentation deals with exact algorithms for the standard version of the RCPSP assuming a single mode, non-preemption and renewable resources. Recent exact algorithms for this problem combine a branch and bound-based optimization search with principles from constraint programming, boolean satisfiability solving and mixed-integer programming for the branching and the fathoming of the search space. In our presentation, we analyze and enhance two recent exact algorithms by a parallel solving procedure. The latter consists of running the exact algorithm in parallel on an instance with different variable domains which are determined through a preprocessing step based on activity lists. Our results on instances with 60, 90 and 120 jobs show that the efficiency of the exact algorithms strongly varies depending on the predefined search space. Moreover, when employing the best found search space (which is not the smallest), we can improve two recent exact algorithms from the literature.

Burak Gokgur, Izmir University of Economics (with Brahim Hnich, Selin Ozpeynirci)

Mathematical modelling and constraint programming approaches for operation assignment and tool loading problems in flexible manufacturing systems

This study presents mathematical programming and constraint programming models that aim to solve scheduling and tool assignment problems in flexible manufacturing systems. In our problem, there are a number of jobs to be processed on parallel computer numerically controlled machines. Each job requires a set of tools and the number of tools available in the system is limited due to economic restrictions. The problem is to assign the jobs and the required tools to machines and determine the schedule so that the makespan is minimized. A mathematical model and three constraint programming models for this problem are developed and the results of the experimental study are reported. Our empirical study reveals that the constraint programming approach leads to more efficient models when compared to mathematical programming model in terms of solution quality and computation time. This work is supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK).

Derivative-free & simulation-based opt.

Tue.3.H 3503

Novel approaches in derivative-free optimization

Organizers/Chairs Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory · Invited Session

Yurii Nesterov, UCL

Random gradient-free minimization of convex functions

In this talk, we prove the complexity bounds for methods of Convex Optimization based only on computation of the function value. The search directions of our schemes are normally distributed random Gaussian vectors. It appears that such methods usually need at most n times more iterations than the standard gradient methods, where n is the dimension of the space of variables. This conclusion is true both for nonsmooth and smooth problems. For the later class, we present also an accelerated scheme with the expected rate of convergence $O(\frac{n^2}{k^2})$, where k is the iteration counter. For Stochastic Optimization, we propose a zero-order scheme and justify its expected rate of convergence $O(\frac{n}{k^{1/2}})$. We give also some bounds for the rate of convergence of the random gradient-free methods to stationary points of nonconvex functions, both for smooth and nonsmooth cases. Our theoretical results are supported by preliminary computational experiments.

Afonso Bandeira, Princeton University (with Katya Scheinberg, Luis Nunes Vicente)

On sparse Hessian recovery and trust-region methods based on probabilistic models

In many application problems in optimization, one has little or no correlation between problem variables, and such (sparsity) structure is unknown in advance when optimizing without derivatives. We will show that quadratic interpolation models computed by l1-minimization recover the Hessian sparsity of the function being modeled, when using random sample sets. Given a considerable level of sparsity in the unknown Hessian of the function, such models can achieve the accuracy of second order Taylor ones with a number of sample points (or observations) significantly lower than $O(n^2)$.

The use of such modeling techniques in derivative-free optimization led us to the consideration of trust-region methods where the accuracy of the models is given with some positive probability. We will show that as long as such probability of model accuracy is over $1/2$, one can en-

sure, almost surely, some form of convergence to first and second order stationary points.

Alexander Rakhlin, University of Pennsylvania (with Alekh Agarwal, Dean Foster, Daniel Hsu, Sham Kakade)

Regret minimization with zeroth order information

The problem of stochastic convex optimization with the noisy zeroth order oracle can be seen as a generalization of the classical multi-armed bandit problem, if the goal is to minimize regret rather than the final value of the objective. Regret is defined as the average of the function values along the optimization path, and not all convex optimization methods have low regret. In this talk we present a regret-minimization algorithm that is based on the zeroth order algorithm of Nemirovskii and Yudin from the 70's. We also briefly discuss regret minimization in a more difficult scenario of online linear optimization, where the linear cost functions are changing adversarially at every step. While we only have one shot at getting any information about the cost function per step, a randomized method which explores according to the Dikin ellipsoid is shown to enjoy a near-optimal regret bound.

Finance & economics

Tue.3.H 3027

Applications and algorithms

Chair Galina Vakulina, Ural State University of Railway Transport

Emilie Joannopoulos, Université de Sherbrooke (with François Dubeau, Jean-Pierre Dussault, Candido Pomar)

Feeding cost optimization of several diet formulations and environmental impact in the swine industry

The diet formulation is a classic example of mathematical programming. We present several new models applied to the swine industry, where feed represent more than 70% of the total production cost, and compare the cost and environmental impact with the traditional feeding solution. Modern producers feed pigs with a 3 phases system with fixed energy rate. First, we will explain the classic and multiphase feeding models. This last one is unrealistic in practice so we introduce two formulation, one so called fixed and the other so called free. The so called free premix model departs from the traditional linear programming formulation in tackling simultaneously the diet's premix contents and the daily proportions, resulting in a bi-linear formulation. Just by using a daily phase feeding system and two pre-mixes, producers already save. Deeper analysis of the problem revealed that the cost of a premix increases with its energy rate. So we finally present the unfixed energy rate model and show how it is related to the previously presented models. The free energy rate free premix bi-linear model appears to give substantial improvements over more traditional solutions.

Takahashi Satoshi, Graduate School of Systems and Information Engineering, University of Tsukuba (with Yoichi Izunaga, Maiko Shigeno, Satoshi Takahashi, Naoki Watanabe)

2-approximation algorithms for the winner determination problem in VCG based single-item multi-unit auctions

This paper studies the winner determination problem in Vickrey-Clarke-Groves (VCG) based single-item multi-unit auctions: given a set of bids in such an auction, find an allocation of units of an item to bidders that maximizes the seller's revenue. (The seller can keep some units of the item.) This problem is known to be NP-hard. We thus propose two simple 2-approximation algorithms for the problem. One is a linear time algorithm and the other is a greedy algorithm. Numerical experiments and human subject experiments were conducted to evaluate the computational efficiency and economic efficiency of these approximation algorithms. Our results are as follows. (1) Approximate ratios of the algorithms are at least 95% in numerical experiments. (2) Under-bidding was observed in human subject experiments although the VCG mechanism theoretically induces bidders to tell their valuation truthfully.

Galina Vakulina, Ural State University of Railway Transport

Project risks analysis using approach of fuzzy sets theory

The report presents a method of analysis of the riskiness of the project using fuzzy sets. The net present value or NPV used as the main indicator of the effectiveness of the project. If the NPV takes value less than zero, the project is considered to be ineffective. The main objective of the work is describing a method to calculate the probability that the project will be ineffective. The method is to consider all the variables of the system as fuzzy numbers with certain characteristics. Function NPV can be represented as a combination of fuzzy parameters and is also a fuzzy number. Different versions of membership functions that can describe the parameters of the project and the number of NPV can be considered. The method is used in practice for the proposed business plan of the project.

Game theory

Tue.3.MA 043

New LCP-based market equilibrium algorithms

Organizer/Chair Vijay Vazirani, Georgia Tech · Invited Session

Yinyu Ye, Stanford University (with Chuangyin Dang, Zhisu Zhu)

A FPTAS for computing a symmetric Leontief competitive economy equilibrium

We consider a linear complementarity problem (LCP) arisen from the Arrow-Debreu competitive economy equilibrium with Leontief utilities. We prove that the decision problem, to decide whether or not there exists a complementary solution, is NP-complete even when the coefficient matrix is symmetric. But under certain conditions, an LCP solution is guaranteed to exist and represent a symmetric Leontief economy equilibrium. Then, we present a fully polynomial-time approximation scheme (FPTAS) for approximating a complementary solution. Our method is based on solving a quadratic social utility optimization problem. We also develop an interior-point path-following algorithm for the problem when the coefficient matrix is non-symmetric. Based on an extended Sard theorem, we construct an almost surely regular homotopy for the system. We report preliminary computational results which show that our methods are practically effective.

Jugal Garg, IIT Bombay (with Ruta Mehta, Milind Sohoni, Vijay Vazirani)

A complementary pivot algorithm for markets under separable piecewise-linear concave utilities

Using the powerful machinery of the LCP and Lemke's algorithm, we give a practical algorithm for computing an equilibrium for Arrow-Debreu markets under separable, piecewise-linear concave (SPLC) utilities, despite the PPAD-completeness of this case. As a corollary, we obtain the first elementary proof of existence of equilibrium for this case.

In 1975, Eaves had given such an algorithm for the case of linear utilities and had asked for an extension to the piecewise-linear, concave utilities. Our result settles the relevant subcase of his problem as well as the problem of Vazirani and Yannakakis of obtaining a path following algorithm for SPLC markets, thereby giving a direct proof of membership in PPAD.

We also prove that SPLC markets have an odd number of equilibria (up to scaling), hence matching the classical result of Shapley about 2-Nash equilibria, which was based on Lemke-Howson algorithm.

For the linear case, Eaves had asked for a combinatorial interpretation of his algorithm. We provide this and it yields a particularly simple proof of the fact that the set of equilibrium prices is convex.

Ruta Mehta, IIT Bombay (with Jugal Garg, Vijay Vazirani)

LCP and Lemke-type algorithm for markets with production

Building on the works of Eaves and Garg, Mehta, Sohoni and Vazirani, we obtain an LCP that captures exactly the set of equilibria for Arrow-Debreu and Fisher markets with separable, piecewise-linear concave (SPLC) utilities and SPLC production, and we also give a complementary pivot algorithm for finding an equilibrium. This answers a question asked by Eaves in 1975. As corollaries, we obtain a proof of PPAD-completeness, an elementary proof of existence of equilibrium (i.e., without using a fixed point theorem), rationality, and oddness of the number of equilibria. Experiments show that our algorithm is practical.

Global optimization

Tue.3.H 2053

From quadratic through factorable to black-box global optimization

Organizer/Chair Leo Liberti, École Polytechnique · Invited Session

Laurent Dumas, University of Versailles (with Frederic Delbos, Eugenio Echague)

A new global optimization method based on a sparse grid metamodel

A new global optimization method is presented here aimed at solving a general black-box optimization problem where function evaluations are expensive. Our work is motivated by many problems in the oil industry, coming from several domains like reservoir engineering, molecular modeling, engine calibration and inverse problems in geosciences. Even if evolutionary algorithms are often a good tool to solve these problems, they sometimes need too many function evaluations, especially in high-dimension cases. To overcome this difficulty, we propose here a new approach, called SGOM, using the Sparse Grid interpolation method with a refinement process as metamodel.

Christodoulos Floudas, Princeton University (with Ruth Misener)

Globally optimizing mixed-integer quadratically-constrained quadratic programs (MIQCQP)

A general framework for deterministically addressing mixed-integer quadratically-constrained quadratic programs (MIQCQP) to

epsilon-global optimality is introduced. Algorithmic components include: reformulating user input, detecting special mathematical structure, generating tight convex relaxations, dynamically generating cuts, partitioning the search space, bounding variables, and finding feasible solutions.

We also discuss computational experience with the global mixed-integer quadratic optimizer, GloMIQO. New components in GloMIQO include integrating a validated interval arithmetic library, dynamically adding alphaBB cuts and higher-order edge-concave cuts, addressing discrete/discrete and discrete/continuous products, selectively adding bilinear terms for RLT cuts, and eliminating bilinear terms based on knapsack constraint inferences. Data is presented for globally optimizing a range of MIQCQP including process networks, computational geometry, and quadratic assignment problems.

Angelos Tsoukalas, Massachusetts Institute of Technology (with Alexander Mitsos)

Extension of McCormick's composition to multi-variate outer functions

G. P. McCormick [Math Prog 1976] provides the framework for the convex/concave relaxations of factorable functions involving functions of the form $F \circ f$, where F is a univariate function. We give a natural reformulation of McCormick's Composition theorem which allows for a straight forward extension to multi-variate outer functions. In addition to extending the framework, we show how the result can be used in the construction of relaxation proofs. A direct consequence is an improved relaxation for the product of two functions which is at least as tight and some times tighter than McCormick's result. We also apply the composition result to the minimum/maximum and the division of two functions yielding an improvement on the current relaxation. Finally we interpret McCormick's Composition theorem as a decomposition approach to the auxiliary variable reformulation methods and we introduce some ideas for future hybrid variations.

Implementations & software

Tue.3.H 1058

NLP and MINLP software

Organizer/Chair Hande Benson, Drexel University · Invited Session

Hande Benson, Drexel University (with Umit Saglam)

MILANO and mixed-integer second-order cone programming

In this talk, we present details of MILANO (mixed-integer linear and nonlinear optimizer), a Matlab-based toolbox for solving mixed-integer optimization problems. Our focus will be on interior-point methods for second-order cone programming problems and their extensions to mixed-integer second-order cone programming problems and nonlinear programs with second-order cone constraints. Numerical results from portfolio optimization, supply chain management, and data mining will be presented.

Klaus Schittkowski, University of Bayreuth (with Oliver Exler, Thomas Lehmann)

MISQP: A TR-SQP algorithm for the efficient solution of non-convex, non-relaxable mixed-integer nonlinear programming problems

We present a new sequential quadratic programming (SQP) algorithm stabilized by trust-regions for solving nonlinear, non-convex and non-relaxable mixed-integer optimization problems. The mixed-integer quadratic programming subproblems are solved by a branch-and-cut algorithm. Second order information is updated by a modified quasi-Newton update formula [BFGS] applied to the Lagrange function for continuous, but also for integer variables. The design goal is to solve practical optimization problems based on expensive executions of an underlying simulation program. Thus, the number of simulations or function evaluations, respectively, is our main performance criterion to measure the efficiency of the code. Numerical results are presented for a set of 175 mixed-integer test problems and different parameter settings of MISQP. The average total number of function evaluations of the new mixed-integer SQP code is about 1,200 including those needed for approximating partial derivatives.

Robert Vanderbei, Princeton University

Fast fourier optimization

Many interesting and fundamentally practical optimization problems, ranging from optics, to signal processing, to radar and acoustics, involve constraints on the Fourier transform of a function. The fast Fourier transform (fft) is a well-known recursive algorithm that can dramatically improve the efficiency for computing the discrete Fourier transform. However, because it is recursive, it is difficult to embed into a linear optimization problem. In this talk, we explain the main idea behind the fast Fourier transform and show how to adapt it so as to make it encodable as constraints in an optimization problem. We demonstrate a real-world problem from the field of high-contrast imaging. On this problem, dramatic improvements are translated to an ability to solve

problems with a much finer discretization. As we shall show, in general, the "fast Fourier" version of the optimization constraints produces a larger but sparser constraint matrix and therefore one can think of the fast Fourier transform as a method of sparsifying the constraints in an optimization problem.

Integer & mixed-integer programming

Tue.3.H 2013

Advances in mixed integer programming

Organizer/Chair Alexander Martin, FAU Erlangen-Nürnberg · Invited Session

Timo Berthold, ZIB / Matheon

Measuring the impact of primal heuristics

In modern MIP-solvers like the branch-cut-and-price-framework SCIP, primal heuristics play a major role in finding and improving feasible solutions at the early steps of the solution process.

However, classical performance measures for MIP such as time to optimality or number of branch-and-bound nodes reflect the impact of primal heuristics on the overall solving process rather badly. Reasons for this are that they typically depend on the convergence of the dual bound and that they only consider instances which can actually be solved within a given time limit.

In this talk, we discuss the question of how the quality of a primal heuristic should be evaluated and introduce a new performance measure, the "primal integral". It depends on the quality of solutions found during the solving process as well as on the point in time when they are found. Thereby, it assesses the impact of primal heuristics on the ability to find feasible solutions of good quality, in particular early during search.

Finally, we discuss computational results for different classes of primal heuristics that are implemented in SCIP.

Manfred Padberg, NYU

The rank of (mixed-) integer polyhedra

We define a purely geometrical notion of the rank of (mixed-) integer rational polyhedra that differs substantially from the existing notions found in the literature. This talk will outline the notion and present some related results.

Felipe Serrano, ZIB (with Daniel Espinoza)

Some computational experiments with multi-row cuts.

We consider a general mixed integer problem (MIP). The topic we address is to derive cuts by combining two or more rows of the optimal simplex tableau of the linear relaxation of the MIP. A framework will be presented that allows to generate multi-row cuts using different relaxations over the main set possibly including bounds on the variables. Specifically, in this talk we present a numerical approach that allows to look into more complex relaxations than those previously considered in the literature. We propose an approximation scheme that may prove useful for practical implementations of multi-row cuts. Also, we incorporate a simple way to take advantage of the integrality of non basic variables.

Integer & mixed-integer programming

Tue.3.H 2032

Trends in mixed integer programming V

Organizers/Chairs Andrea Lodi, University of Bologna; Robert Weismantel, ETH Zurich · Invited Session

Tiziano Parriano, DEIS - University of Bologna (with Alberto Caprara, Antonio Frangioni)

An analysis of natural approaches for solving multicommodity-flow problems

We study the relative performances of three existing approaches to solve the minimum-cost linear MultiCommodity Flow Problem (MCFP). The first approach is solving the LP corresponding to the natural node-arc formulation with state-of-the-art, general-purpose commercial software. The second is to take advantage of the block-diagonal structure with complicating constraints of the LP to develop Dantzig-Wolfe decomposition/column generation approaches. The third is a decomposition-based pricing procedure, proposed by Mamer and McBride, in which the same subproblems of the D-W decomposition are used to identify new columns in a reduced master problem that has the same structure of the node-arc formulation. With a particular focus on *degeneracy* and *instability* issues of the column generation, different classes of MCFP instances are solved in order to study the connections between the structure of a specific instance and the performances of the most common solving approaches for this class of problems. This may be useful in choosing the correct approach when a particular MCFP

shall be solved, as well as improving the effectiveness of the approaches themselves.

Alexandra Newman, Colorado School of Mines (with Ed Klotz)

Practical guidelines for solving difficult linear and mixed integer programs

The advances in state-of-the-art hardware and software have enabled the inexpensive, efficient solution of many large-scale linear and linear integer programs previously considered intractable. However, a significant number of real-world linear and linear integer programs can still require hours, or even days, of run time and are not guaranteed to yield an optimal (or near-optimal) solution. In this talk, we present suggestions for diagnosing and removing performance problems in commercially available linear and mixed integer programming solvers, and guidelines for careful model formulation. We draw on examples from the mining and energy industries, among other areas.

Integer & mixed-integer programming

Tue.3.H 2033

Location problems

Chair Wilbert Wilhelm, Texas A&M University

Alfredo Marín, Universidad de Murcia

Discrete ordered non-linear median problem with induced order

The Discrete Ordered Median Problem (DOMP) has many discrete location problems as particular cases. Some examples are the p -median problem, the p -center problem, the k -centrum problem and several equitable location problems.

In the DOMP, distances between medians and allocated points are sorted. The sorted distances are then multiplied times a vector of coefficients which determines the particular problem that is being solved. Sorting values of variables inside a linear integer programming formulation was a matter of past research.

In this work we deal with an extension of the DOMP where the order in which the variables are multiplied by the coefficients is determined by a second set of variables. That is to say, pairs of variables are sorted with respect to the first component of the pair, and it is the second component which is multiplied by the coefficients. In this way, new problems can be modeled at the expense of increasing the difficulty of the formulation.

We also show that non linear objective functions can be incorporated to the formulation without additional effort. The results of a preliminary computational study will be presented.

Wilbert Wilhelm, Texas A&M University (with David Carmona, Xue Han, Brittany Tarin)

The stochastic healthcare facility configuration problem

The stochastic healthcare facility configuration problem, which is essentially a supply chain design problem, is to prescribe the location and size of each facility, allowing openings, expansions, contractions, and closures; the healthcare services each is to offer; and the capacity to be allocated to each service - all given that patient needs are uncertain. This topic is timely as countries seek to enhance access to healthcare services, including the U.S., which is working towards the goal of expanding access in underserved (e.g., rural) areas and through recent legislation. This presentation describes relevant practical features of the healthcare facility configuration problem and presents a framework for prescriptive models. Appropriate solution methods are proposed. The goal is a scalable methodology to plan healthcare-facility configuration, adjusting, for example, to demand and demographic changes, emigration, immigration, mergers, and acquisitions.

Logistics, traffic, and transportation

Tue.3.H 0106

Exact approaches to routing problems

Chair Stefan Ropke, Technical University of Denmark

Vladimir Deineko, Warwick Business School

A framework for vehicle routing

We consider the capacitated vehicle routing problem (VRP) and various modifications of this problem. We suggest a general framework which is flexible enough to be used for all these modifications of the VRP. The main algorithm behind the framework is the well-known Held & Karp dynamic programming algorithm for the travelling salesman problem. Results of computational experiments on the known bench-

mark problems show the competitiveness of our approach with the best known heuristics.

Carlos Cardonha, IBM Research - Brazil (with Ralf Borndörfer)

A fast solution method applied to the vehicle positioning problem and its multi-periodic, online, and robust extension

The Vehicle Positioning Problem (VPP) is a classical and challenging combinatorial optimization problem that deals with the assignment of vehicles of a transport company to parking positions. In this talk, we present an exact solution technique that explores partial knowledge about the likelihood of having certain variables in optimal solutions in order to produce feasible solutions for MIPs quickly. We present an exact algorithm for the VPP based on this method and show through computational experiments that it is able to provide optimal solutions for large-scale scenarios of the problem. We also show that some important extensions of the VPP - namely, its multi-periodic version, which was previously intractable, and its online version - can be solved efficiently with this method. Finally, we also discuss how one can apply the concept of robustness to the problem and how robust solutions can be efficiently computed for the VPP.

Stefan Ropke, Technical University of Denmark

Exact and heuristic solution methods for the generalized asymmetric vehicle routing problem and the capacitated arc routing problem

In the generalized asymmetric vehicle routing problem (GAVRP) one is given a set of nodes consisting of customer nodes and a depot. Customer nodes are partitioned into clusters and one must construct a number of routes, starting and ending at the depot, such that exactly one customer from each cluster is visited. Each cluster has a certain demand and routes must be constructed such that the total demand on a route is below a given threshold. We solve the GAVRP with an exact method, based on the branch-and-cut-and-price paradigm, as well as with a parallel adaptive large neighborhood search heuristic. Furthermore, in [Baldacci, Bartolini and Laporte (2010)] it was shown how an instance of the capacitated arc routing problem (CARP) easily could be transformed into a GAVRP instance. We use this transformation in order to solve CARP instances with the proposed GAVRP algorithms and report on extensive computational experiments for both problem types.

Logistics, traffic, and transportation

Tue.3.H 0111

Approximation algorithms for supply chain management and logistics optimization models

Organizer/Chair Retsef Levi, MIT Sloan School of Management - Invited Session

Tim Carnes, Link Analytics (with David Shmoys)

A primal-dual approximation algorithm for air ambulance routing and deployment

We present a primal-dual 2-approximation algorithm for the k -location routing problem, that models choosing k locations for vehicles and routing each vehicle in a tour to serve a set of requests, where the cost is the total tour length. This is the first constant approximation algorithm for this problem and has real-world applications; this is part of a broader effort for Ornge, which transports medical patients. Our work builds and improves upon work of Goemans & Williamson and Jain & Vazirani.

Gonzalo Romero, Massachusetts Institute of Technology (with Retsef Levi, Georgia Perakis)

Allocating subsidies to minimize a commodity's market price - a network design approach

We study the problem faced by a central planner allocating subsidies to competing firms that provide a commodity, with the objective of minimizing its market price, subject to a budget constraint and possibly upper bounds on the total amount that can be allocated to each firm. We consider two types of subsidies, co-payments and technology subsidies. We use a network design under equilibrium flow approach to model an endogenous market response to the subsidy allocation, and obtain structural results and near optimal solutions in various important cases.

Adam Elmachtoub, MIT (with Retsef Levi)

Supply chain management with online customer selection

We consider new online versions of supply chain management and logistics models, where in addition to production decisions, one also has to decide on which customers to serve. Specifically, customers arrive sequentially during a selection phase, and one has to decide whether to accept or reject each customer upon arrival. If a customer is rejected, then a lost-sales cost is incurred. Once the selection decisions are all made, one has to satisfy all the accepted customers with minimum possible production cost. The goal is to minimize the total cost of lost-sales

and production. A key feature of the model is that customers arrive in an online manner, and the decision maker does not require any information about future arrivals. We provide several novel algorithms for online customer selection problems which are based on new variants of repeated optimization and interesting connections to cooperative game theory. For many important settings, our algorithms achieve competitive ratio guarantees that are close to best possible.

Mixed-integer nonlinear programming

Tue.3.MA 005

Convex relaxations for nonconvex optimization problems

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Kurt Anstreicher, University of Iowa (with Sam Burer)

Second-order cone constraints for extended trust-region subproblems

The classical trust-region subproblem (TRS) minimizes a nonconvex quadratic objective over the unit ball. We consider extensions of TRS having additional constraints. It is known that TRS, and the extension of TRS that adds a single linear inequality, both admit convex programming representations. We show that when two parallel linear inequalities are added to TRS, the resulting nonconvex problem has an exact convex representation as a semidefinite programming (SDP) problem with additional linear and second-order-cone constraints. For the case where an additional ellipsoidal constraint is added to TRS, resulting in the well-known "two trust-region subproblem" (TTRS), we describe a new relaxation including second-order-cone constraints that significantly strengthens the usual SDP relaxation. Numerical experiments show that the strengthened relaxation provides an exact solution of TTRS in most instances, although the theoretical complexity of TTRS remains an open problem.

Jeff Linderoth, University of Wisconsin-Madison (with Jim Luedtke, Ashutosh Mahajan, Mahdi Namazifar)

Solving mixed integer polynomial optimization problems with MINOTAUR

We study methods for building polyhedral relaxations of multilinear terms that arise in nonconvex mixed integer optimization problems. The goal is to obtain a formulation that is more compact than the convex hull formulation, but yields tighter relaxations than the standard McCormick relaxation. We present computational results for an approach based on grouping the variables into subsets that cover all multilinear terms in the problem. The approach is combined with additional reformulation techniques and spatial branching in the software framework MINOTAUR to produce a solver for mixed integer polynomial optimization problems.

Jon Lee, University of Michigan

Global optimization of indefinite quadratics

I will talk on some methodology for global optimization of indefinite quadratics.

Multi-objective optimization

Tue.3.H 1029

Applications of multiobjective optimization

Chair Gennady Zabudsky, Omsk Branch of Sobolev Institute of Mathematics Siberian Branch of Russian Academy of Sciences

Ceren Tuncer Şakar, Middle East Technical University (with Murat Köksalan)

Effects of multiple criteria and different planning horizons on portfolio optimization

Portfolio optimization is the problem of allocating available resources between different investments in the market. Following the pioneering work of Markowitz, Modern Portfolio Theory -which has two criteria of mean return and variance- has emerged and several approaches to the problem have been proposed. Incorporating multiple criteria to portfolio optimization and considering multi-period settings are important. Considering return, liquidity, variance and Conditional Value at Risk, we look into the effects of multiple criteria on the decision and objective spaces of portfolio optimization problems. We also employ Stochastic Programming to handle multi-period portfolio optimization and compare the effects of using different planning horizons. We demonstrate our results based on tests performed with stocks traded on Istanbul Stock Exchange.

Lino Alvarez-Vazquez, Universidad de Vigo (with Nestor Garcia-Chan, Aurea Martinez, Miguel Vazquez-Mendez)

Air pollution and industrial plant location: A multi-objective optimization approach

In this talk we deal with the problem of choosing the optimal location for a new industrial plant, considering the framework of numeri-

cal simulation and multi-objective optimal control of partial differential equations (PDE). We take into account both ecological and economic objectives, and we look not only for the optimal location of the plant but also for the optimal management of its emissions to atmosphere. With these purposes in mind, we propose a mathematical model (a system of parabolic PDE) to simulate air pollution and, based on this model, we formulate the problem in the framework of multi-objective optimal control. This problem is studied here from a cooperative point of view, looking for Pareto-optimal solutions. A numerical algorithm (via a characteristics-Galerkin discretization of the adjoint model) is proposed, and preliminary numerical results for a hypothetical situation in the region of Galicia (NW Spain) are also presented.

Gennady Zabudsky, Omsk Branch of Sobolev Institute of Mathematics Siberian Branch of Russian Academy of Sciences (with Igor Amzin)

Optimal location of rectangles on parallel lines

Facility location problems in the plane play an important role in mathematical programming. In the report is studied the problem of location rectangles on parallel lines such that a length and a width of rectangular cover were minimum. The problem is NP-hard. For the search of Pareto-optimal solutions we use models of integer linear programming and dynamic programming techniques. An algorithm for the search of the approximate solution of the problem with the minimum length is offered. We use IBM ILOG CPLEX package for the solution of integer linear programming problems. Results of computing experiment are presented.

Nonlinear programming

Tue.3.H 0107

Interior-point methods

Chair Mouna Hassan, Rey Juan Carlos University

Li-Zhi Liao, Hong Kong Baptist University

A study of the dual affine scaling continuous trajectories for linear programming

In this talk, a continuous method approach is adopted to study both the entire process and the limiting behaviors of the dual affine scaling continuous trajectories for linear programming. Since the approach is different from any existing one, many new theoretical results on the trajectories resulted from the dual affine scaling continuous method model for linear programming are obtained.

Atsushi Kato, Tokyo University of Science (with Hiroshi Yabe, Hiroshi Yamashita)

An interior point method with a primal-dual quadratic barrier penalty function for nonlinear semidefinite programming

In this talk, we consider a primal-dual interior point method for nonlinear semidefinite programming:

$$\begin{cases} \min & f(x), & x \in \mathbf{R}^n, \\ \text{s.t.} & g(x) = 0, & X(x) \succeq 0, \end{cases}$$

where functions $f: \mathbf{R}^n \rightarrow \mathbf{R}$, $g: \mathbf{R}^n \rightarrow \mathbf{R}^m$ and $X: \mathbf{R}^n \rightarrow \mathbf{S}^p$ are sufficiently smooth, and \mathbf{S}^p denotes the set of p -th order real symmetric matrices.

Our method is consists of the outer iteration (SDPIP) and the inner iteration (SDPLS). Algorithm SDPIP finds a KKT point. Algorithm SDPLS also finds an approximate shifted barrier KKT point. Specifically, we apply the Newton method to the shifted barrier KKT conditions. To globalize the method, we propose a differentiable merit function in the primal-dual space within the framework of line search strategy. We show its global convergence property.

Mouna Hassan, Rey Juan Carlos University (with Javier Mogueerza, Andrés Redchuk)

The l_1 -Penalty Interior Point Method

The problem of general nonconvex, nonlinear constraint optimization is addressed, without assuming regularity conditions on the constraints, and the problem can be degenerate. We reformulate the problem by applying l_1 -exact penalty function with shift variables to relax and regularize the problem. Then a feasible type line search primal-dual interior point method, approximately solve a sequence of inequality constraint penalty-barrier subproblems. To solve each subproblems, a Cauchy step would be computed beside to Newton step and the proposed algorithm would move along a direction in the span of these two steps. The penalty parameter is checked at the end of each iteration as we do with the barrier parameter, since we do not need to update the penalty parameter before performing the line search. If the multipliers are finite, then the corresponding penalty parameter is finite. Global convergence properties do not require the regularity conditions on the original problem. The solution to the penalty-barrier problem converge to the optima that may satisfy the Karush-Kuhn-Tucker point or Fritz-John point, and may satisfy a first-order critical point for the measure of the

Nonlinear programming

Tue.3.H 0110

Recent advances in nonlinear optimization

Organizer/Chair Andrew Conn, T. J. Watson Research Center · Invited Session

Nicholas Gould, STFC Rutherford Appleton Laboratory (with Sven Leyffer, Yueling Loh, Daniel Robinson) SQP Filter methods without a restoration phase

We consider Filter SQP methods in which regularization is applied explicitly rather than via a trust-region, as suggested by Gould, Leyffer et al. in 2006. Our goal is to provide an alternative to the unattractive “restoration” phase that is needed to unblock iterates that become trapped by the filter. We will consider two alternatives. In the first, the model problem itself gives precedence to improving feasibility and this naturally leads to unblocking. In the second, the filter envelope is “tilted” to allow more room for improvement, and if this fails to unblock, the filter itself is disregarded and progress towards optimality guided by an overall merit function. All of this is somewhat speculative at this stage.

Philip Gill, University of California, San Diego (with Daniel Robinson)

Regularization and convexification for SQP methods

We describe a sequential quadratic programming (SQP) method for nonlinear programming that uses a primal-dual generalized augmented Lagrangian merit function to ensure global convergence. Each major iteration involves the solution of a bound-constrained subproblem defined in terms of both the primal and dual variables. A convexification method is used to give a subproblem that is equivalent to a regularized convex quadratic program (QP).

The benefits of this approach include the following: (1) The QP subproblem always has a known feasible point. (2) A projected gradient method may be used to identify the QP active set when far from the solution. (3) The application of a conventional active-set method to the bound-constrained subproblem involves the solution of a sequence of regularized KKT systems. (4) Additional regularization may be applied by imposing explicit bounds on the dual variables. (5) The method is equivalent to the stabilized SQP method in the neighborhood of a solution.

Andreas Waechter, Northwestern University (with Travis Johnson)

A hot-started NLP solver

We discuss an active-set SQP method for nonlinear continuous optimization that avoids the re-factorization of derivative matrices during the solution of the step computation QP in each iteration. Instead, the approach uses hot-starts of the QP solver for a QP with matrices corresponding to an earlier iteration, or available from the solution of a similar NLP. The goal of this work is the acceleration of the solution of closely related NLPs, as they appear, for instance, during strong-branching or diving heuristics in MINLP.

Nonlinear programming

Tue.3.H 0112

Real-time optimization III

Organizers/Chairs Victor Zavala, Argonne National Laboratory; Sebastian Sager, Universität Magdeburg · Invited Session

Markus Kögel, OVG Universität Magdeburg (with Rolf Findeisen)

On real-time optimization for model predictive control using multiplier methods and Nesterov's gradient method

Model predictive control is an optimization based approach in automatic control to control systems. It allows taking constraints explicitly into account while optimizing the performance. Model predictive control requires solving in real-time optimization problem each time a new measurement becomes available.

We focus on the important special case of linear plants, quadratic cost criterions and convex constraints, in which the optimization problems are quadratic programs with a special structure. Although, multiple efficient algorithms exist by now, model predictive control is still challenging for fast, large systems or on embedded systems with limited computing power.

Therefore we present approaches using multiplier methods and Nesterov's gradient method, which allow efficient real-time optimization. In particular, we outline how the solution can be parallelized or distributed. This enables the use of multiple processor cores or even multiples computers to decrease the solution time. We illustrate the proposed algorithms using application examples.

Gabriele Pannocchia, Department of Chemical Engineering (DICCISM) - University of Pisa (with Mayne David, Rawlings James)

On the convergence of numerical solutions to the continuous-time constrained LQR problem

A numerical procedure for computing the solution to the continuous-time infinite-horizon constrained linear quadratic regu-

lator was presented in [1], which is based successive strictly convex QP problems where the decision variables are the control input value and slope at selected grid points. Each QP generates an upper bound to the optimal cost, and the accuracy is increased by using gradually refined grids computed offline to avoid any online integration. In this work we propose an adaptive method to gradually refine the grid where it is most needed, still without having to perform integration online, and we address the convergence properties of such algorithm as the number of grid points is increased. By means of suitable optimality functions, at each iteration given the current upper bound cost, we compute: (i) a lower bound approximation of the optimal cost which can be used to stop the algorithm within a guaranteed tolerance; (ii) for each grid interval, an estimate of the cost reduction that can be obtained by bisecting it. Examples are presented.

[1] G. Pannocchia, J.B. Rawlings, D.Q. Mayne, W. Marquardt, IEEE Trans. Auto. Contr. 55 (2010), pp. 2192-2198.

Eric Kerrigan, Imperial College London (with George Constantinides, Stefano Longo, Juan Jerez)

Breaking away from double-precision floating-point in interior point solvers

We will show how one can modify interior point methods for solving constrained linear quadratic control problems in computing hardware with a fixed-point number representation or with significantly less bits than in single- or double-precision floating-point. This allows one to dramatically reduce the computational resources, such as time, silicon area and power, needed to compute the optimal input sequence at each sample instant. For fixed precision, we propose a simple preconditioner, which can be used with iterative linear solvers such as CG or MINRES, that allows one to compute tight bounds on the ranges of the variables in the Lanczos iteration, thereby allowing one to determine the best position of the radix point. To allow one to reduce the number of bits needed, we propose the use of the delta transform of Middleton and Goodwin in order to avoid numerical errors that would occur when using the usual shift transform to discretize the continuous-time optimal control problem. We also propose a Riccati method, tailored to the delta transform, for efficiently solving the resulting KKT systems that arise within an interior point solver.

Nonsmooth optimization

Tue.3.H 1012

Large-scale structured optimization

Organizer/Chair Anatoli Juditsky, LJK, Université J. Fourier · Invited Session

Arkadi Nemirovski, Georgia Institute of Technology (with Anatoli Juditsky, Fatma Kilinc-Karzan)

Randomized first-order algorithms for bilinear saddle point problems and their applications to ℓ_1 minimization

In this talk, we propose randomized first-order algorithms for solving bilinear saddle point problems. Our developments are motivated by the need for sublinear time algorithms to solve large-scale parametric bilinear saddle point problems where cheap online assessment of solution quality is crucial. We present the theoretical efficiency estimates of our algorithms and discuss a number of applications, primarily to the problems of ℓ_1 minimization arising in sparsity-oriented Signal Processing. We demonstrate, both theoretically and by numerical examples, that when seeking for medium-accuracy solutions of large-scale ℓ_1 minimization problems, our randomized algorithms outperform significantly (and progressively as the sizes of the problems grow) the state-of-the-art deterministic methods.

Guanghui Lan, University of Florida (with Saeed Ghadimi)

Stochastic first- and zero-order methods for nonconvex stochastic programming

We present a new stochastic approximation (SA) type algorithm, namely the randomized stochastic gradient (RSG) method, for solving a class of nonlinear (possibly nonconvex) stochastic programming problems. We establish the rate of convergence of the method for computing an approximate stationary point of a nonlinear programming problem. We also show that this method can handle stochastic programming problems with endogenous uncertainty where the distribution of random variables depend on the decision variables. We discuss a variant of the algorithm which consists of applying a post-optimization phase to evaluate a short list of solutions generated by several independent runs of the RSG method. We show that such modification allows to improve significantly the large-deviation properties of the algorithm. We also develop a special version of the method for solving a class of simulation-based optimization problems in which only stochastic zero-order information is available.

Sergey Shpirko, Moscow Institute of Phys. & Tec. (with Yurii Nesterov)

Primal-dual subgradient method for huge-scale conic optimization problems and its applications in structural design

For huge-scale optimization problems, we suggest a new primal-

dual subgradient method. It generates the main minimization sequence in the dual space. At the same time, it constructs an approximate primal solution. Our scheme is based on the recursive updating technique suggested recently by Nesterov. It allows a logarithmic dependence of the total cost of subgradient iteration in the number of variables.

As an application, we consider a classical problem of finding an optimal design of mechanical structures. Such a problem can be posed in a conic form, with high sparsity of corresponding linear operator.

Optimization in energy systems

Tue.3.MA 549

Optimization for power grids

Organizers/Chairs Arvind Raghunathan, Mitsubishi Electric Research Labs; Victor Zavala, Argonne National Laboratory · Invited Session

Arvind Raghunathan, Mitsubishi Electric Research Labs (with Daniel Nikovski)

Global optimization of power flow problems

We consider the solution of optimal power flow (OPF) problems with discrete variables. The discrete variables model changes in transformer positions. The problem falls into the category of non-convex mixed integer nonlinear programs (MINLP). We propose efficient solution techniques for solving the OPF to global optimality. The performance of the method will be illustrated on several problems from the literature.

Sean Harnett, Columbia University (with Daniel Bienstock, Michael Chertkov)

Robust DCOPF

We present a formulation for affine control of generator output to compensate for uncertain output of renewable sources. The robustness of the formulation is achieved through SOCP constraints; we present a scalable formulation and numerical experiments.

Naiyuan Chiang, University of Edinburgh (with Andreas Grothey)

Solving SCOPF problems by a new structure exploiting interior point method

The aim of this paper is to demonstrate a new approach to solve the linearized ($n - 1$) security constrained optimal power flow (SCOPF) problem by OOPS, which is a modern structure-exploiting primal-dual interior-point (IPM) implementation.

Firstly, we present a reformulation of the SCOPF model, in which most matrices that need to be factorized are constant. Consequently, most factorizations and a large number of backsolve operations only need to be performed once throughout the IPM iterations.

Moreover, we suggest to use a preconditioned iterative method to solve the corresponding linear system when we assemble the Schur complement matrix. We suggest several schemes to pick a good and robust preconditioner based on combining different "active" contingency scenarios. We give results on several SCOPF test problems. The largest example contains 500 buses. We compare the results from the original IPM implementation in OOPS and our new approaches.

Optimization in energy systems

Tue.3.MA 550

Mathematical optimization for mid-term operation planning in gas networks

Organizer/Chair Marc Steinbach, Leibniz Universität Hannover · Invited Session

Björn Geißler, FAU Erlangen-Nürnberg, Discrete Optimization (with Alexander Martin, Antonio Morsi, Lars Schewe)

A new approach for solving MINLPs applied to gas network optimization

We present a new approach to solve MINLPs which is based on the construction of MIP-relaxations of arbitrary tightness. To construct these relaxations we extend some well-known MIP-techniques for piecewise linear approximations with the aid of convex underestimators and concave overestimators such that the resulting MIP-model is a proper relaxation of the underlying MINLP. After solving these relaxations, we fix the values of the integer variables and solve the remaining NLP. We apply our algorithm to the gas network nomination validation problem and provide numerical evidence for its suitability on small as well as on large-scale real-life instances.

Bernhard Willert, Leibniz Universität Hannover (with Martin Schmidt, Marc Steinbach)

A high accuracy optimization model for gas networks

Despite new regulations in the gas market and increasingly challenging transport situations, often gas transport networks are still balanced manually by using simulation software. The application of a high accuracy optimization model would increase the network efficiency and decrease the operational costs. We will present a suitable optimization

model supporting different levels of detail for gas physics and technical network elements. Numerical results will underline its accuracy compared to a commercial simulation software and its practicability will be shown.

Jesco Humpola, Zuse Institute Berlin (with Benjamin Hiller, Thomas Lehmann, Robert Schwarz, Jonas Schweiger)

Topology optimization for nonlinear network flows

A gas network consists of active elements such as valves and compressors, and passive elements like pipelines between sources and sinks. Most of the elements are pipelines where the flow is induced by a non-linear and non-convex relationship of the pressure differences at their end nodes. The topology optimization problem is to determine a cost-optimal physical state of each active element in order to transport a specified flow through the network without violating physical or operational constraints. This is modeled as a mixed integer non-linear program. Discrete decisions correspond to active network elements, and the non-linearity originates from described gas flow properties. A sub-problem of this model has several convex relaxations. We present a framework which yields a global optimal solution for this large-scale topology optimization problem. This is implemented as a special tailored combination of the solvers SCIP and IPOPT. Preliminary computational results based on real-world instances with several hundred nodes and about 3000 arcs are presented. The data for this study is provided by Open Grid Europe GmbH (OGE), the leading German gas transportation company.

PDE-constrained opt. & multi-level/multi-grid meth.

Tue.3.MA 415

Optimization applications in industry II

Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics · Invited Session

Stefan Ulbrich, TU Darmstadt (with J. Carsten Ziemer)

Multilevel optimization based on adaptive discretizations and reduced order models for engineering applications

We consider optimization problems governed by partial differential equations. Multilevel techniques use a hierarchy of approximations to this infinite dimensional problem and offer the potential to carry out most optimization iterations on comparably coarse discretizations. Motivated by engineering applications we discuss the efficient interplay between the optimization method, adaptive discretizations of the PDE, reduced order models derived from these discretizations, and error estimators. To this end, we describe an adaptive multilevel SQP method that generates a hierarchy of adaptive discretizations during the optimization iteration using adaptive finite-element approximations and reduced order models such as POD. The adaptive refinement strategy is based on a posteriori error estimators for the PDE-constraint, the adjoint equation and the criticality measure. The resulting optimization methods allow to use existing adaptive PDE-solvers and error estimators in a modular way. We demonstrate the efficiency of the approach by numerical examples for engineering applications.

Martin Grepl, RWTH Aachen University (with Mark Kärcher)

A certified reduced basis approach for parametrized linear-quadratic optimal control problems

The solution of optimal control problems governed by partial differential equations (PDEs) using classical discretization techniques such as finite elements or finite volumes is computationally very expensive and time-consuming since the PDE must be solved many times. One way of decreasing the computational burden is the surrogate model based approach, where the original high-dimensional model is replaced by its reduced order approximation. However, the solution of the reduced order optimal control problem is suboptimal and reliable error estimation is therefore crucial.

In this talk, we present error estimation procedures for linear-quadratic optimal control problems governed by parametrized parabolic PDEs. To this end, we employ the reduced basis method as a surrogate model for the solution of the optimal control problem and develop rigorous and efficiently evaluable a posteriori error bounds for the optimal control and the associated cost functional. Besides serving as a certificate of fidelity for the suboptimal solution, our a posteriori error bounds are also a crucial ingredient in generating the reduced basis with greedy algorithms.

Irwin Yousept, TU-Berlin

PDE-constrained optimization involving eddy current equations

Eddy current equations consist of a coupled system of first-order PDEs arising from Maxwell's equations by neglecting the displacement current. Applications of such equations can be found in many modern technologies such as in induction heating, magnetic levitation, optimal

design of electromagnetic meta-materials, and many others. In this talk, we discuss several PDE-constrained optimization problems involving time-harmonic eddy current equations as equality constraints. Recent theoretical and numerical results are presented.

Robust optimization

Tue.3.MA 004

Applications of robust optimization II

Organizer/Chair Allison O'Hair, MIT · Invited Session

Allison O'Hair, MIT (with Dimitris Bertsimas)

Adaptive, dynamic and robust optimization to learn human preferences

In 1944, in one of the most influential works of the twentieth century, John von Neumann and Oskar Morgenstern developed the idea of expected utility theory to make decisions under uncertainty. In 1979, Daniel Kahneman and Amos Tversky, in their Nobel prize winning work, presented a critique of expected utility theory by observing that some of its axioms violate human behavior. Specifically, people are loss averse, are inconsistent and evaluate outcomes with respect to deviations from a reference point. However, they did not propose a constructive method to learn preferences that adhere to the new principles. In this work, we use robust and integer optimization in an adaptive and dynamic way to determine preferences that are consistent with human behavior in agreement with the critique of Kahneman and Tversky. We use robust linear optimization to model loss averse behavior, integer optimization to correct for inconsistent behavior and choice-based conjoint analysis in an adaptive questionnaire to dynamically select pairwise questions. We have implemented an online software that uses the proposed approach and report empirical evidence of its strength.

Andy Sun, IBM Thomas J. Watson Research Center (with Dimitris Bertsimas, Eugene Litvinov, Jinye Zhao, Tongxin Zheng)

Adaptive robust optimization for the security constrained unit commitment problem

Unit commitment, one of the most critical tasks in electric power system operations, faces new challenges as the supply and demand uncertainty increases dramatically due to the integration of variable generation resources such as wind power and price responsive demand. To meet these challenges, we propose a two-stage adaptive robust unit commitment model for the security constrained unit commitment problem in the presence of nodal net injection uncertainty. Compared to the conventional stochastic programming approach, the proposed model is more practical in that it only requires a deterministic uncertainty set, rather than a hard-to-obtain probability distribution on the uncertain data. The unit commitment solutions of the proposed model are robust against all possible realizations of the modeled uncertainty. We develop a practical solution methodology based on a combination of Benders decomposition type algorithm and the outer approximation technique. We present an extensive numerical study on the real-world large scale power system operated by the ISO New England, which demonstrates the economic and operational advantages of our model over the current practice.

Nathan Kallus, Massachusetts Institute of Technology (with Dimitris Bertsimas, Mac Johnson)

The power of optimization over randomization in designing controlled trials

The purpose of a controlled trial is to compare the effects of a proposed drug and a null treatment. Random assignment has long been the standard and aims to make groups statistically equivalent before treatment. By the law of large numbers, as the sample grows, randomized groups grow similar almost surely. However, with a small sample, which is practical reality in many disciplines, randomized groups are often too dissimilar to be useful for any inference at all. To remedy this situation, investigators faced with difficult or expensive sampling usually employ specious assignment schemes to achieve better-matched groups, and without theoretical motivation they then employ probabilistic significance tests, whose validity is questionable. Supplanting probabilistic hypothesis testing with a new theory based on robust optimization, we propose a method we call robust hypothesis testing that assigns subjects optimally and allows for mathematically rigorous inference that does not use probability theory and which is notable for allowing inference with small samples. We provide empirical evidence that suggests that optimization leads to significant advantages over randomization.

Robust optimization

Tue.3.MA 042

Theory of robust optimization

Organizer/Chair Dick Den Hertog, Tilburg University · Invited Session

Dick Den Hertog, Tilburg University (with Aharon Ben-Tal, Jean-Philippe Vial)

Deriving robust counterparts of nonlinear uncertain inequalities

We provide a structured way to construct the robust counterpart for a nonlinear uncertain inequality that is concave in the uncertain parameters. We use convex analysis (support functions, conjugate functions, Fenchel duality) in order to convert the robust counterpart into an explicit and computationally tractable set of constraints. It turns out that to do so one has to calculate the support function of the uncertainty set and the concave conjugate of the nonlinear constraint function. Surprisingly, these two computations are completely independent. This approach has several advantages. First, it provides an easy, structured, way to construct the robust counterpart both for linear and nonlinear inequalities. Second, it shows that for new classes of uncertainty regions and for new classes of nonlinear optimization problems tractable counterparts can be derived. Third, it paves the way to a new, more flexible, Globalized Robust Counterpart approach.

Bram Grissen, Tilburg University (with Aharon Ben Tal, Hans Blanc, Dick Den Hertog)

Tractable robust counterparts of linear conic optimization problems via their duals

We propose a new way to derive the tractable robust counterpart of a linear conic optimization problem. For the dual of a robust optimization problem, it is known that the uncertain parameters of the primal problem become optimization variables in the dual problem ("primal worst is dual best"). We give a convex reformulation of the dual problem of a robust linear conic program. When this problem is bounded and satisfies the Slater condition, strong duality holds. We show how to construct the primal optimal solution from the dual optimal solution. Our result allows many new uncertainty regions to be considered that were previously intractable, e.g., the set of steady state probability vectors of a Markov chain with uncertain transition probabilities, or the set of vectors whose Bregman or phi-divergence distance to a given vector is restricted. Our result also makes it easy to construct the robust counterpart for intersections of uncertainty regions. The description of the uncertainty region is in the constraints of the dual optimization problem, so using intersections of uncertainty regions is as simple as adding constraints for all uncertainty regions involved.

Ulrich Pferschy, University of Graz (with Michele Monaci)

On the robust knapsack problem

We consider an uncertain variant of the knapsack problem that arises when the exact weight of each item is not exactly known in advance but belongs to a given interval, and the number of items whose weight differs from the nominal value but attains an arbitrary value in this interval is bounded by a constant. We analyze the worsening of the optimal solution value with respect to the classical knapsack problem, and exactly determine its worst-case performance depending on uncertainty for all parameter configurations. In addition, we perform the same analysis for the fractional version of the problem and provide an efficient, nontrivial algorithm for its solution. Finally, we derive the worst-case performance ratio of the fractional problem and of a variant of the greedy algorithm for the robust knapsack problem.

Sparse optimization & compressed sensing

Tue.3.H 1028

Algorithms for sparse optimization I

Organizer/Chair Andreas Tillmann, TU Darmstadt · Invited Session

Andreas Tillmann, TU Darmstadt (with Dirk Lorenz, Marc Pfetsch)

Heuristic optimality check and computational solver comparison for basis pursuit

The problem of finding a minimum ℓ_1 -norm solution to an underdetermined linear system is an important problem in compressed sensing, where it is also known as basis pursuit. We propose a heuristic optimality check (HOC) as a general tool for ℓ_1 -minimization, which often allows for early termination by "guessing" a primal-dual optimal pair based on an approximate support. Moreover, we provide an extensive numerical comparison of various state-of-the-art ℓ_1 -solvers that have been proposed during the last decade. The computational evaluation also includes a novel subgradient algorithm which employs adaptive

approximate projections using conjugate gradients, and provides empirical evidence for the effectiveness of the proposed HOC.

Spartak Zikrin, Linköping University (with Mats Andersson, Oleg Burdakov, Hans Knutsson)

Sparse optimization techniques for solving multilinear least-squares problems with application to design of filter networks

The multilinear least-squares (MLLS) problem is an extension of the linear least-squares problem. The difference is that a multilinear operator is used in place of a matrix-vector product. The MLLS is typically a large-scale problem characterized by a large number of local minimizers. Each of the local minimizers is singular and non-isolated. The MLLS problem originates, for instance, from the design of filter networks.

For the design of filter networks, we consider the problem of finding optimal sparsity of the sub-filters that compose the network. This results in a MLLS problem augmented by an additional constraint that poses an upper limit on the number of nonzero components in the solution. This sparse multilinear least-squares problem is NP-hard. We present an approach for approximately solving the problem. In our numerical experiments, a greedy-type sparse optimization algorithm is used for designing 2D and 3D filter networks.

The efficiency of our approach is illustrated by results of numerical experiments performed for some problems related to the design of filter networks.

Maxim Demenkov, Russian Academy of Sciences

Real-time linear inverse problem and control allocation in technical systems

Control allocation is a set of methods for control of modern overactuated mechanical systems (such as aircrafts, marine vehicles, electric cars), and deals with distributing of the total control demand among the individual actuators. The idea of control allocation allows to deal with control constraints and actuator faults separately from the design of the main regulator, which uses virtual control input. Its dimension is usually quite low, while the number of physical actuators can be much higher. Using linearization, control allocation is equivalent to linear inverse problem with interval-constrained vector x , which we need to recover from limited linear measurements: $y = Ax$. Depending on the particular application, one can seek a sparse solution (which minimizes number of physical actuators used for control) or optimize convex function of x . Note that if x is constrained to a hypercube, then y is constrained to its image, a zonotope. We propose a new real-time method for calculating x , which is based on interval analysis ideology. Its basic operations are hypercube bisection and explicit reconstruction of the zonotope as a system of linear inequalities.

Stochastic optimization

Tue.3.MA 141

Advances in stochastic programming

Organizer/Chair Daniel Kuhn, Imperial College London · Invited Session

Angelos Georgioulis, Imperial College London (with Daniel Kuhn, Wolfram Wiesemann)

A stochastic capacity expansion model for the UK energy system

Energy markets are currently undergoing one of their most radical changes in history. Both market liberalisation and the increasing penetration of renewable energy sources highlight the need to accommodate uncertainty in the design and management of future energy systems. This work aims to identify the most cost-efficient expansion of the UK energy grid, given a growing future demand for energy and the target to move towards a more sustainable energy system. To this end, we develop a multi-stage stochastic program where the investment decisions (generation capacity that should be built) are taken here-and-now, whereas the operating decisions are taken in hourly time stages over a horizon of 30 years. The resulting problem contains several thousand time stages and is therefore severely intractable. We develop a novel problem reformulation, based on the concept of time randomisation, that allows us to equivalently reformulate the problem as a two-stage stochastic program. By taking advantage of the simple structure of the decision rule approximation scheme, we can model and solve a problem that optimises over the whole generation capacity of the UK energy system.

Panos Pappas, Imperial College London

Dimensionality reduction and a maximum principle for multiscale stochastic processes

Weakly connected Markov Processes are often used to capture stochastic dynamics that evolve along different time scales. We show that if the system has sufficient scale separation then a Maximum Principle of reduced order holds. The reduced order Maximum Principle is

used to develop a solution algorithm for the optimisation of multiscale processes.

Daniel Kuhn, Imperial College London (with Melvyn Sim, Wolfram Wiesemann)

Polyhedrality in distributionally robust optimization

Distributionally robust optimization studies stochastic programs whose uncertain parameters follow a distribution that is itself uncertain. The distribution is only known to belong to an ambiguity set defined in terms of certain statistical or structural properties, and the decision-maker is assumed to hedge against the worst-case distribution within the ambiguity set. Most distributionally robust optimization problems studied to date rely on mean, covariance and support information about the uncertain parameters. These problems can often be reformulated as semidefinite programs, which are computationally tractable in theory but suffer from limited scalability in practice. In this talk we propose new uncertainty models specified in terms of maximum variability bounds with polyhedral integrands, minimum variability bounds with polyhedral integrands and polyhedral confidence sets, respectively. We employ these ambiguity sets in the context of standard and risk-averse stochastic programming as well as chance constrained programming, and we show that the resulting distributionally robust optimization problems admit highly scalable reformulations or approximations as linear programs.

Stochastic optimization

Tue.3.MA 144

Nonlinear stochastic optimization

Chair Marcus Poggi, PUC-Rio Informatica

Kathrin Klamroth, University of Wuppertal (with Markus Kaiser)

Modeling uncertainties in location-allocation problems: A stochastic programming approach

Knowledge about the future development of the planning area and the environmental conditions is highly important for location decisions. We consider continuous location-allocation problems with Weber objectives where uncertainty not only occurs in the demand of the existing facilities (that is, in the location objective), but also in the constraints of the problem such as the size and the shape of the feasible region. The trade-off between the cost of a solution on one hand and its robustness with respect to the uncertain data on the other hand is analyzed, which naturally motivates a multiple objective formulation of the problem. A two-stage stochastic programming model is obtained as a scalarization of the multiple objective model, and the relations to single-objective location-allocation problems are discussed. We use geometric arguments to derive discretization results for the case that distances are measured by block norms or polyhedral gauges. An efficient location-allocation heuristic for problems with uncertain feasible sets is suggested and tested on problem data with up to 2000 demand nodes, 10 different scenarios and 10 new facilities.

Eugenio Mijangos, University of the Basque Country (UPV/EHU)

An algorithm for nonlinearly-constrained nonlinear two-stage stochastic problems

We put forward an algorithm to solve nonlinearly-constrained two-stage stochastic problems with a nonlinear objective function. It is based on the Twin Node Family (TNF) concept involved in the Branch-and-Fix Coordination method. These problems have continuous and binary variables in the first stage and only continuous variables in the second stage. The nonanticipativity constraints are fulfilled by TNF strategy. In this work, given that the objective function is nonlinear, we propose to solve each nonlinear subproblem generated in the nodes of the trees associated with this method by solving sequences of quadratic subproblems. If the nonlinear constraints are convex we approximate them by means of outer linear approximations; otherwise, we relax these constraints by using augmented Lagrangian techniques. These methods have been implemented in C++ with the help of Cplex 12.1 to solve only the quadratic approximations. The test problems have been randomly generated by using a C++ code developed by this author. Numerical experiments have been performed and its efficiency has been compared with that of BONMIN (COIN-OR). Results are promising.

Marcus Poggi, PUC-Rio Informatica (with Bruno Flach)

On a class of stochastic programs with endogenous uncertainty: Algorithm and applications

We study a class of stochastic programming problems with endogenous uncertainty - i.e., those in which the probability distribution of the random parameters is decision-dependent - which is formulated as a Mixed Integer Non-Linear Programming (MINLP) problem. The proposed methodology consists of: (i) a convexification technique for polynomials of binary variables; (ii) an efficient cut-generation algorithm; and (iii) the incorporation of importance sampling concepts into

the stochastic programming framework so as to allow the solution of large instances of the problem. We discuss the error tolerance of the approach and its impact on the resulting algorithm efficiency. Computational results are obtained in the context of the humanitarian logistics problem, they demonstrate the effectiveness of the proposed methodology by solving instances significantly larger than those reported in related works. Other applications in this class of stochastic problems are presented.

Stochastic optimization

Tue.3.MA 376

Approximation algorithms for stochastic combinatorial optimization

Organizer/Chair Chaitanya Swamy, University of Waterloo · Invited Session

Inge Goertz, Technical University of Denmark (with Viswanath Nagarajan, Rishi Saket)

Stochastic vehicle routing with recourse

We study the classic Vehicle Routing Problem in the setting of stochastic optimization with recourse. StochVRP is a two-stage optimization problem, where demand is satisfied using two routes: fixed and recourse. The fixed route is computed using only a demand distribution. Then after observing the demand instantiations, a recourse route is computed – but costs here become more expensive by a factor λ . We present an $O(\log^2 n \log(n\lambda))$ -approximation algorithm for this stochastic routing problem, under arbitrary distributions. The main idea in this result is relating StochVRP to a special case of submodular orienteering, called knapsack rank-function orienteering. We also give a better approximation ratio for knapsack rank-function orienteering than what follows from prior work. Finally, we provide a Unique Games Conjecture based $\omega(1)$ hardness of approximation for StochVRP, even on star-like metrics on which our algorithm achieves a logarithmic approximation.

Ramamoorthi Ravi, Tepper School of Business at Carnegie Mellon Univ (with Anupam Gupta, Ravishankar Krishnaswamy, Marco Molinaro)

Approximation algorithms for correlated knapsacks and non-martingale bandits

We give constant-factor approximation algorithms for the stochastic knapsack problem with correlations and cancelations, and also for some budgeted learning problems where the martingale condition is not satisfied, using similar ideas. Indeed, we can show that previously proposed linear programming relaxations for these problems have large integrality gaps. We propose new time-indexed LP relaxations; using a decomposition and “shifting” approach, we convert these fractional solutions to distributions over strategies, and then use the LP values and the time ordering information from these strategies to devise a randomized scheduling algorithm. We hope our LP formulation and decomposition methods may provide a new way to address other correlated bandit problems with more general contexts.

The paper is available at <http://arxiv.org/abs/1102.3749>

Gwen Spencer, Cornell University (with David Shmoys)

Fragmenting and vaccinating graphs over time and subject to uncertainty: Developing techniques for wildfire and invasive species containment

Decisions about the containment of harmful processes that spread across landscapes (for example, wildfire and invasive species) often must be made under uncertainty and as the system evolves in time. Not all resources are available immediately and containment efforts may fail to prevent spread. The valuable probabilistic predictions produced by ecologists and foresters have been under-utilized because of the difficulty of optimizing when stochastic features and spatial connectedness (or, in this case, disconnectedness) interact.

I will introduce several simple models in graphs that generalize existing work in the CS theory literature and explain provably-good algorithmic results for several settings. These models capture qualitative tradeoffs with important implications for sustainable management. How should resources for wildfire containment be divided across preventive fuel removals and real-time fire suppression efforts, and how can these deployments be coordinated to maximum advantage? If attempts to block invasive species spread are not perfectly reliable, but redundancy is costly, where should managers concentrate their resources?

Telecommunications & networks

Tue.3.H 3002

Communication network design

Chair Youngho Lee, Korea University

Marc Ruiz, Universitat Politècnica de Catalunya (with Jaume Comellas, Luis Velasco)

Multi-constructive meta-heuristic for the metro areas design problem in hierarchical optical transport networks

Optical connections in flexgrid-based optical networks will be able to convey up to 1 Tbps in the near future. Before designing those core networks however, it is required to introduce some hierarchy defining metropolitan areas so to reduce the number of locations participating in the core network. Those areas are then interconnected through the core network, and so expenditure costs of the latter can be dramatically reduced by minimizing the amount of traffic to be handled. As a result of the problem complexity we propose an iterative meta-heuristic that, at each iteration, builds a feasible solution by applying either a greedy-randomized or a pure random constructive procedure. To reach local optima, a local search procedure is afterwards applied. Finally, diversification is exploited by applying path-relinking between new and elite solutions. The performance of single and multi-constructive meta-heuristics was compared against exact solutions obtained from an ILP model. Finally, a real instance from a nation-wide network operator was solved. This work was supported by the Spanish science ministry through the TEC2011-27310 ELASTIC project.

Jonad Pulaj, ZIB (with Anastasios Giovanidis)

Models for network design under varied demand structures

Recent developments in capacitated network design encourage further generalizations of the problem over finite time periods. Thus, the multiperiod network design problem (MNDP) consists in (1) establishing the network topology, (2) installing capacities, and (3) routing communication demands, while taking into account the fluctuations of demands over the design time horizon and minimizing installation costs. In this talk, we present new models and solution algorithms for the MNDP. Among other useful techniques, we derive lower bounds using Lagrangian relaxation and examine approximation algorithms. We evaluate the effectiveness of our new approaches through computational experience conducted on a number of networks, including realistic instances derived from the survivable network design library (SNDLib). This work is developed as part of a joint German-Polish project on multiperiod network optimization. The goal of the project is to develop efficient mathematical models for capacity expansions over finite time periods.

Youngho Lee, Korea University (with Chanwoo Park, Gigyong Park, Junsang Yuh)

A nonlinear mixed integer programming problem in designing local access networks with QoS constraints.

In this talk, we present nonlinear mixed integer programming models for solving the local access network design problem with QoS constraints. The problem is a two-level hierarchical location-allocation problem on the tree topology of local access networks. The objective function of the problem minimizes the total cost of fiber link and switches, while satisfying both the capacity of switches within the prescribed level of quality of service. In developing an exact optimal algorithm, we develop a new approach of the reformulation linearization technique (RLT) by linearizing the nonlinear QoS constraints by implementing mixed-integer linear constraints with auxiliary variables. By exploiting the special structure of the problem, we devise an outer approximation algorithm that implements cut generation strategies for cutting off the violated solution at each iteration. Computational results are presented for demonstrating the effectiveness of cut generation strategies.

Variational analysis

Tue.3.H 2035

Control and optimization of impulsive systems II

Organizers/Chairs Dmitry Karamzin, Computing Centre RAS; Fernando Pereira, Porto University-FEUP/Institute for Systems and Robotics Porto · Invited Session

Aram Arutyunov, Peoples' Friendship University of Russia (with Dmitry Karamzin, Fernando Pereira)

The R.V. Gamkrelidze's maximum principle for state constrained optimal control problem: Revisited

We study necessary conditions of optimality for optimal control problem with state constraints in the form of the Pontryagin's maximum principle (for short MP). For problems with state constraints these conditions were first obtained by R.V. Gamkrelidze in 1959 and subsequently published in the classic monograph by the four authors. This MP was obtained under a certain regularity assumption on the optimal trajectory. Somewhat later, in 1963, A.Ya. Dubovitskii and A.A. Milyutin proved another MP for problems with state constraints. In contrast with

the MP of R.V. Gamkrelidze, this MP was obtained without a priori regularity assumptions, but it degenerates in many cases of interest what was discovered and studied later. Here, we suggest a MP in the form proposed by R.V. Gamkrelidze without any a priori regularity assumptions on the optimal trajectory. However, without a priori regularity assumptions, this MP may degenerate. Therefore, we prove that, under certain additional conditions of controllability relatively to the state constraints at the end-points, or regularity of the control process, degeneracy will not occur, since a stronger non-triviality condition will be satisfied.

Elena Goncharova, Institute for System Dynamics and Control Theory, SB RAS (with Maxim Staritsyn)
Impulsive systems with mixed constraints

We consider an optimal control problem for an impulsive hybrid system. Such a dynamical system can be described by a nonlinear measure differential equation under mixed constraints on a state trajectory and a control measure. The constraints are of the form

$$Q_-(x(t-)) = 0, \quad Q_+(x(t)) = 0, \\ \Psi(x(t-)) \leq 0, \quad \Psi(x(t)) \leq 0 \quad \nu\text{-a.e. on } [0, T].$$

Here, $x(t-)$, $x(t)$ are the left and right limits of a state trajectory x at time t , a non-negative scalar measure ν is the total variation of an “impulsive control”, and $\nu([0, T]) \leq M$ with $M > 0$. Such conditions can be also regarded as state constraints of equality and inequality type qualified to hold only over the set where ν is localized. A time reparameterization technique is developed to establish a result on the problem transformation to a classical optimal control problem with absolutely continuous trajectories. Based on this result, a conceptual approach is proposed to design numerical methods for optimal impulsive control. We give some results on numerical simulation of a double pendulum with a blockable degree of freedom.

Laurent Pfeiffer, Inria-Saclay and CMAP, Ecole Polytechnique (with Joseph Bonnans, Oana Serea)
Sensitivity analysis for relaxed optimal control problems with final-state constraints

We consider a family of relaxed optimal control problems with final-state constraints, indexed by a perturbation variable y . Our goal is to compute a second-order expansion of the value $V(y)$ of the problems, near a reference value of y . We use relaxed controls, i.e., the control variable is at each time a probability measure. Under some conditions, a constrained optimal control problem has the same value as its relaxed version.

The specificity of our study is to consider bounded strong solutions [2], i.e., local optimal solutions in a small neighborhood (for the L^∞ -distance) of the trajectory. To obtain a sharp second-order upper estimate of V , we derive two linearized problem from a wide class of perturbations of the control (e.g., small perturbations for the L^1 -distance). Relaxation permits a very convenient linearization the problems. Using the decomposition principle [1], we prove that the upper estimate is an exact expansion.

[1] J.F. Bonnans, N.P. Osmolovskiĭ. Second-order analysis of optimal control problems with control and final-state constraints. 2010.

[2] A.A. Milyutin, N.P. Osmolovskiĭ. Calculus of variations and optimal control. 1998.

Variational analysis

Tue.3.H 2051

Recent advances on linear complementarity problems

Organizer/Chair Héctor Ramírez, Universidad de Chile · Invited Session

Julio Lopez, Universidad Técnica Federico Santa María (with Rúbén López, Héctor Ramírez)

Characterizing Q-linear transformations for linear complementarity problems over symmetric cones

In this work, we introduce a new class, called \mathbf{F} , of linear transformations defined on a Euclidean Jordan algebra. This concept is illustrated in some known examples of Euclidean Jordan algebras: n -dimensional vectors, quadratic forms and n -dimensional symmetric matrices. Also, within this new class, we show the equivalence between \mathbf{Q} - and \mathbf{Q}_b -transformations. We also provide conditions under which a linear transformation belongs to \mathbf{F} . Finally, we present some examples of transformation: Lyapunov, Quadratic, Stein and relaxation transformation.

Jean-Baptiste Hiriart-Urruty, Paul Sabatier University (Toulouse III) (with Hai Yen Le)

A variational approach of the rank function

We consider here the rank (of a matrix) from the variational viewpoint. Actually, besides being integer-valued, the rank function is lower-semicontinuous. We are interested in the rank function, because it appears as an objective (or constraint) function in various modern optimization problems, the so-called rank minimization problems (\mathcal{P}). A problem like (\mathcal{P}) has some bizarre and/or interesting properties, from the optimization or variational viewpoint. The first one, well documented

and used, concerns the “relaxed” forms of it. We recall here some of these results and propose further developments:

- (Global optimization) Every admissible point in (\mathcal{P}) is a local minimizer.
- (Moreau-Yosida approximation) The Moreau-Yosida approximate (or regularized version) of the objective function in (\mathcal{P}), as well as the associated proximal mapping, can be explicitly calculated.
- (Generalized subdifferentials) The generalized subdifferentials of the rank function can be determined. Actually, all the main ones coincide and their common value is a vector subspace!

Héctor Ramírez, Universidad de Chile (with Rúbén López, Julio López)

Existence and stability results based on asymptotic analysis for semidefinite linear complementarity problems

This talk is devoted to the study of existence and stability results of semidefinite linear complementarity problems (for short SDLCP). Our approach consists of approximating the variational inequality formulation of the SDLCP by a sequence of suitable chosen variational inequalities. This provides particular estimates for the asymptotic cone of the solution set of the SDLCP. We thus obtain new coercive and noncoercive existence results, as well as new properties related to the continuity of the solution sets of the SDLCP (such as outer/upper semicontinuity, Lipschitz-type continuity, among others). Moreover, this asymptotic approach leads to a natural extension of the class of García linear transformations, formerly defined in the context of linear complementarity problems, to this SDLCP setting.

Approximation & online algorithms

Wed.1.H 3010

Scheduling and packing: Approximation with algorithmic game theory in mind

Organizer/Chair Asaf Levin, The Technion · Invited Session

Leah Epstein, University of Haifa (with Gyorgy Dosa)

Generalized selfish bin packing

In bin packing games, an item has a positive weight and each item has a cost for every valid packing of the items. We study a class of such games where the cost of an item is the ratio between its weight and the total weight of items packed with it, i.e., cost sharing is based linearly on the weights of items. We study several types of pure Nash equilibria (NE): standard NE, strong NE, and strictly/weakly Pareto optimal NE. We show that any game of this class admits all these types of equilibria. We study the (asymptotic) prices of anarchy and stability (PoA and PoS) of the problem for these types of equilibria and general/unit weights. While the case of general weights is strongly related to First Fit, and all the PoA values are 1.7, for unit weights they are all below 1.7. The strong PoA is equal to approximately 1.691 (another well-known number in bin packing) while the strictly Pareto optimal PoA is lower. The PoS values are 1, except for those of strong equilibria, which is 1.7 for general weights, and approximately 1.611824 for unit weights.

Asaf Levin, The Technion (with Leah Epstein, Rob van Stee)

A unified approach to truthful scheduling on related machines

We present a unified framework for designing deterministic monotone PTAS's for a wide class of scheduling problems on uniformly related machines. This class includes (among others) minimizing the makespan, maximizing the minimum load, and minimizing the l_p norm of the machine loads vector. Previously, this kind of result was only known for the makespan objective. Monotone PTAS's have the property that an increase in the speed of a machine cannot decrease the amount of work assigned to it, and have an important role in mechanism design.

The key idea of our novel method is to show that it is possible to compute in polynomial time a structured nearly optimal schedule. An interesting aspect of our approach is that, in contrast to all known PTAS's, we avoid rounding any job sizes or speeds throughout. We can therefore find the exact best structured schedule using a dynamic programming. The state space encodes sufficient information such that no postprocessing is needed, allowing an elegant and relatively simple analysis. The monotonicity is a consequence of the fact that we find the best schedule in a specific collection of schedules.

Rob van Stee, Max Planck Institute for Informatics (with Xujin Chen, Benjamin Doerr, Xiaodong Hu, Weidong Ma, Carola Winzen)

The price of anarchy for selfish ring routing is two

We analyze the network congestion game with atomic players, asymmetric strategies, and the maximum latency among all players as social cost. While this is an important social cost function, it has so far received relatively little attention in the literature. We show that the price of anarchy is at most two, when the network is a ring and the link latencies are linear. This bound is tight. This is the first sharp bound for the maximum latency objective on a natural and important network topology.

Combinatorial optimization

Wed. 1.H 3004

Extended formulations in discrete optimization II

Organizers/Chairs Gautier Stauffer, University Bordeaux 1 – INRIA; Volker Kaibel, Otto-von-Guericke Universität Magdeburg · Invited Session

Mathieu Van Vyve, Université catholique de Louvain (with Laurence Wolsey)

Projecting an extended formulation

What can be done when faced with a hard MIP for which a strong extended formulation is known, but is too large to be used in a branch-and-bound framework? One possible approach is as follows. Given an extended formulation $Q = \{(x, w) \in \mathbb{R}^n \times \mathbb{R}^q \mid Bx + Dw \geq d\}$ and an objective $\min c^T x$, we would like to efficiently derive a strong relaxation $P = \{x \in \mathbb{R}^n \mid Ax \geq b\}$ in the original variable space. To be more specific, we would like the inequalities $Ax \geq b$ to be at the same time: (i) such that the optimal solution sets of optimizing over P or Q are the same, (ii) small: the number of inequalities is not too large, or even minimal, so that $Ax \geq B$ can efficiently replace $Bx + Dw \geq d$ in branch-and-bound, (iii) efficiently computable, (iv) individually strong: each of the inequality is ideally a facet of $\text{proj}_x(Q)$, (v) collectively strong: P is a strong relaxation of $\text{proj}_x(Q)$. We formalize these different requirements, discuss their compatibility, describe a practical scheme for solving MIPs for which a strong-but-too-large extended formulation is known, and present some computational experiments.

Kanstantsin Pashkovich, University of Magdeburg (with Volker Kaibel)

Constructing extended formulations using polyhedral relations

There are many examples of optimization problems whose associated polyhedra can be described much nicer, and with way less inequalities, by projections of higher dimensional polyhedra than this would be possible in the original space. However, currently not many general tools to construct such extended formulations are available. Here, we develop a framework of polyhedral relations that generalizes inductive constructions of extended formulations via projections, and we particularly elaborate on the special case of reflection relations. The latter ones provide polynomial size extended formulations for several polytopes that can be constructed as convex hulls of the unions of (exponentially) many copies of an input polytope obtained via sequences of reflections at hyperplanes. We demonstrate the use of the framework by deriving small extended formulations for the G -permutahedra of all finite reflection groups G (generalizing both Goeman's extended formulation of the permutahedron of size $O(n \log n)$ and Ben-Tal and Nemirovski's extended formulation with $O(k)$ inequalities for the regular $2k$ -gon) and for Huffman-polytopes (the convex hulls of the weight-vectors of Huffman codes).

Dirk Oliver Theis, Otto von Guericke University Magdeburg, Germany (with Troy Lee)

Some lower bounds on sizes of positive semidefinite extended formulations

Among other, similar, statements, we prove the following:
Theorem. Every positive semidefinite extended formulation for the Cut polytope of K_n dominating the 3-clique inequalities must have size at $\Omega(n^2)$.
 (The size of a positive semidefinite formulation is the dimension of the positive semidefinite matrices.) This contrasts the fact that the famous Goemans-Williamson relaxation has linear size: It dominates only a weakened form of the 3-clique inequalities.

Combinatorial optimization

Wed. 1.H 3005

Algorithm for matrices and matroids

Chair Klaus Truemper, University of Texas at Dallas

Matthias Walter, Otto-von-Guericke University Magdeburg (with Klaus Truemper)

A simple algorithm for testing total unimodularity of matrices

There is a significant practical need for an effective test of total unimodularity of matrices. The currently fastest algorithm for that task has complexity $O(n^3)$, where n is the longer dimension of the given matrix. The algorithm would be an excellent candidate for implementation, were it not for numerous structurally complicated cases in several steps that defy implementation with reasonable effort.

We have simplified the algorithm so that all complicated cases are avoided while key ideas are retained. The resulting, much simpler, algorithm has complexity $O(n^5)$, which matches or is close to that of other polynomial testing algorithms of total unimodularity.

The talk describes the simplified algorithm, compares it with the original one, sketches an implementation, and summarizes computa-

tional results for several classes of matrices. The public-domain code is available from several websites.

Leonidas Pitsoulis, University of Thessaloniki (with Kostas Papalamprou)

Decomposition of binary signed-graphic matroids

We employ Tutte's theory of bridges to derive a decomposition theorem for binary matroids arising from signed graphs. The proposed decomposition differs from previous decomposition results on matroids that have appeared in the literature in the sense that it is not based on k -sums, but rather on the operation of deletion of a cocircuit. Specifically, it is shown that certain minors resulting from the deletion of a cocircuit of a binary matroid will be graphic matroids apart from exactly one that will be signed-graphic, if and only if the matroid is signed-graphic.

Combinatorial optimization

Wed. 1.H 3008

Combinatorics and geometry of linear optimization III

Organizers/Chairs Jesus De Loera, University of California, Davis; Antoine Deza, McMaster University · Invited Session

Shinji Mizuno, Tokyo Institute of Technology (with Tomonari Kitahara)

An upper bound for the number of different solutions generated by the primal simplex method with any selection rule of entering variables

Kitahara and Mizuno obtained an upper bound for the number of different solutions generated by the primal simplex method with Dantzig's (the most negative) pivoting rule. In this talk, we extend the result to the primal simplex method with any pivoting rule which chooses an entering variable whose reduced cost is negative at each iteration. We see that the upper bound is fairly tight by using a variant of Klee-Minty's LP. The upper bound is applied to a linear programming problem with totally unimodular matrix. We also get a similar bound for the dual simplex method.

Ilan Adler, University of California, Berkeley

The equivalence of linear programs and zero-sum games

In 1951, Dantzig showed the equivalence of linear programming problems and two-person zero-sum games. However, in the description of his reduction from linear programs to zero-sum games, he noted that there was one case in which the reduction does not work. This also led to incomplete proofs of the relationship between the Minimax Theorem of game theory and the Strong Duality Theorem of linear programming. In this Talk, I fill these gaps. In particular, I'll present two complete strongly polynomial reductions of LP's to zero-sum games, a Karp-type reduction which is applicable to LP's with rational (as well as algebraic) data, and a Cook type reduction which is applicable to LP's with real data. The key for both reductions are procedures to solve a system of linear constraints by an oracle capable of determining either feasibility or unboundedness of the system. I'll also discuss the relationship between the Minimax Theorem and the Strong Duality Theorem.

Uri Zwick, Tel Aviv University (with Oliver Friedmann, Thomas Hansen)

Subexponential lower bounds for randomized pivoting rules for the simplex algorithm

The simplex algorithm is among the most widely used algorithms for solving linear programs in practice. With essentially all deterministic pivoting rules it is known, however, to require an exponential number of steps to solve some linear programs. No non-polynomial lower bounds were known, prior to this work, for randomized pivoting rules. We provide the first subexponential (i.e., of the form $2^{\Omega(n^\alpha)}$, for some $\alpha > 0$) lower bounds for the two most natural, and most studied, randomized pivoting rules suggested to date.

The first randomized pivoting rule considered is random-edge, which among all improving pivoting steps (or edges) from the current basic feasible solution (or vertex) chooses one uniformly at random. The second randomized pivoting rule considered is random-facet, a more complicated randomized pivoting rule suggested by Kalai and by Matoušek, Sharir and Welzl. Our lower bound for the random-facet pivoting rule essentially matches the subexponential upper bounds given by Kalai and by Matoušek et al. Lower bounds for random-edge and random-facet were known before only in abstract settings, and not for concrete linear programs.

Combinatorial optimization

Wed.1.H 3012

Heuristics I

Chair Shunji Umetani, Osaka University

Badri Toppur, Great Lakes Institute of Management

A divide-and-bridge heuristic for Steiner minimal trees on the Euclidean plane

This paper describes the construction of Steiner minimal trees on the Euclidean plane using a divide-and-bridge heuristic. A lexicographically sorted set of terminal sites is divided into subsets. These subsets with three, four or five vertices in each set are created using recursive division by two. The optimal Steiner tree length and topology for each subset are calculated using an exponential time exact algorithm.

Any two neighboring trees calculated above, can be bridged by the edge of shortest length. Because of the repeated division of the given set into halves, an outlying terminal of a subset may better suit the total connectivity if it is included in the neighboring subset. We start with a feasible division that may not be optimal, and then look for the optimal division by moving the boundary between two subsets, if it is promising. Split operations may be required at the terminals of the bridge edge, to obtain the minimal tree for the merged set. After every bridge operation or split operation, the optimal coordinates are calculated by an algorithm, that works in $O(N)$ time since the topology is known.

Yuri Frota, UFF (with Luidi Simonetti)

Upper and lower bounds for the constrained forest problem

Given an undirected edge-weighted graph and a positive integer m , the constrained forest problem (CFP) seeks a covering forest of minimum weight such that each of its tree components contains at least m vertices. This work presents a new heuristic based on a variable neighborhood search (VNS) for this NP-Hard problem. Moreover, this heuristic represents the first step towards the development of an exact branch-and-cut method based on a new mathematical formulation for the CFP. Computational experiments are conducted on benchmark instances found in the literature. We report results showing that the VNS with the proposed strategies improved the solutions given by the previously approximation algorithms. Furthermore, our computational results demonstrate that the new heuristic is competitive with other methodologies, including a genetic algorithm recently proposed in the literature. We also present some preliminary results that indicate the strength of the new formulation.

Shunji Umetani, Osaka University (with Masanao Arakawa, Mutsunori Yagiura)

A heuristic algorithm for the set multicover problem with generalized upper bound constraints

We consider an extension of the set covering problem (SCP) introducing (i) multicover and (ii) generalized upper bound (GUB) constraints. For the conventional SCP, the pricing method has been introduced to reduce the number of variables, and several efficient heuristic algorithms based on this idea have been developed to solve very large-scale instances. However, GUB constraints often make the pricing method less effective, because they prevent solutions from having highly evaluated variables simultaneously. To overcome this, we propose a heuristic algorithm to reduce the size of problem instances that modifies the evaluation scheme of variables taking account of GUB constraints. We also develop an efficient implementation of a local search algorithm with the 2-flip neighborhood that reduces the number of candidates in the neighborhood without sacrificing the solution quality. According to computational comparison on benchmark instances with the latest mixed integer programming solver, our algorithm performs quite effectively for various types of instances, especially for very large-scale instances.

Combinatorial optimization

Wed.1.H 3013

Network flows

Chair Chandra Chekuri, University of Illinois, Urbana-Champaign

Maria Afsharirad, Ferdowsi University of Mashhad (with Hosein Taqizadeh Kakhki)

Maximum dynamic flow interdiction problem

Let $G = (N, A)$ be a directed graph with a given source node s , and a given sink node t . Let $N = (G, u, \tau, r)$ be the associated dynamic network with arc capacities u , flow traversal times τ , and arc interdiction costs r . The problem is to find a set of arcs whose removal will minimize the maximum flow from s to t within a given time period of T , subject to budget limitation. This is in fact the dynamic version of the well known max flow interdiction problem. We present a new formulation based on the concept of temporally repeated flows and discuss two

solution approaches for this problem. Some numerical results will also be presented.

Andreas Karrenbauer, University of Konstanz (with Sabine Cornelsen)

Planar min-cost flow in nearly $O(n^{3/2})$

We present combinatorial algorithms for the min-cost flow problem in planar graphs. Previously, the best known bounds came from algorithms for general graphs using only that the number of arcs is in $O(n)$. These yield near quadratic algorithms and subquadratic ones only for special cases, e.g., $\tilde{O}(n^{7/4})$ time if the optimum objective value is in $O(n)$, or $O(n^{3/2})$ time for bounded costs and capacities. We demonstrate techniques to obtain $O(n^{3/2})$ for planar graphs of bounded degree, constant capacities, and arbitrary costs, or for bidirected planar graphs of bounded face sizes, no capacities, and bounded costs. These conditions come from applications in image processing and in graph drawing, respectively. In the latter case, our result improves a long standing time bound for minimizing the number of bends in an orthogonal drawing of a plane graph. Without these restrictions but with the condition of a linear optimum, we only lose a log-factor, i.e. we get $O(n^{3/2} \log n)$. With a scaling approach, we obtain $O(\sqrt{Un} \log^3 n \log C)$, where U is the sum over all capacities and C is the maximum over all costs.

Chandra Chekuri, University of Illinois, Urbana-Champaign (with Sreeram Kannan, Adnan Raja, Pramod Viswanath)

Multicommodity flows and cuts in polymatroidal networks

The maxflow-mincut theorem for $s - t$ flow is a fundamental theorem in combinatorial optimization. Flow-cut equivalence does not hold in the multicommodity case. Approximate flow-cut gap results have been extensively studied, and poly-logarithmic upper bounds have been established in various settings.

Motivated by applications to information flow in wireless networks, we consider flow-cut gap results in *polymatroidal* networks in which there are submodular capacity constraints on the edges incident to a node. Such networks were introduced by Lawler & Martel and Hassin in the single-commodity setting, and are closely related to the submodular flow model of Edmonds & Giles. The maxflow-mincut theorem for a single-commodity holds in polymatroidal networks. For these networks we obtain the first approximate multicommodity flow-cut gap results that (nearly) match several known results in standard networks. Of technical interest is the use of line-embeddings to round the dual of the flow relaxation rewritten with a convex objective function using the Lovasz-extension of a submodular function.

Combinatorial optimization

Wed.1.H 3021

Routing for public transportation

Organizer/Chair Peter Sanders, Karlsruhe Institute of Technology · Invited Session

Matthias Müller-Hannemann, MLU Halle-Wittenberg

Coping with delays: Online timetable information and passenger-oriented train disposition

In daily operation, railway traffic always deviates from the planned schedule to a certain extent. Primary initial delays of trains may cause a whole cascade of secondary delays of other trains over the entire network.

In this talk, we survey recent results for efficient online timetable information, robust pretrip route planning, stochastic delay propagation, and disposition management. Disposition management solves the decision problem whether a train should wait for incoming delayed trains or not. This problem has a highly dynamic nature due to a steady stream of update information about delayed trains. We propose a new model for real-time train disposition aiming at a passenger-friendly optimization and report about experimental results with a prototypal implementation and test data of German Railways.

Thomas Pajor, Karlsruhe Institute of Technology (with Daniel Delling, Renato Werneck)

Round-based public transit routing

We study the problem of computing all Pareto-optimal journeys in a dynamic public transit network for two criteria: arrival time and number of transfers. Existing algorithms consider this as a graph problem, and solve it using variants of Dijkstra's algorithm. Unfortunately, this leads to either high query times or suboptimal solutions. We take a different approach. We introduce RAPTOR, our novel round-based public transit router. Unlike previous algorithms, it is not Dijkstra-based, looks at each route (such as a bus line) in the network at most once per round, and can be made even faster with simple pruning rules and parallelization using multiple cores. Because it does not rely on preprocessing, RAPTOR works in fully dynamic scenarios. Moreover, it can be easily extended to handle flexible departure times or arbitrary additional criteria,

such as fare zones. When run on London's complex public transportation network, RAPTOR computes all Pareto-optimal journeys between two random locations an order of magnitude faster than previous approaches, which easily enables interactive applications.

Hannah Bast, University of Freiburg

Next-generation route planning: Multi-modal, real-time, personalized

Route planning in static road networks or public transportation networks has reached a very high level of sophistication. The next challenges are: (1) Free combination of the various modes of transportation (walking, biking, driving, public transportation, flight, etc.). (2) Acquire and incorporate dynamic updates in real time (traffic jams, delayed trains, cancelled flights, etc.). (3) Provide personalized result diversity for each user (flexible optimization criteria, time-independent result summaries, etc.). I will talk about the state of the art and some recent advances with respect to these.

Complementarity & variational inequalities

Wed.1.MA 041

Complementarity modeling and its game theoretical applications

Organizer/Chair Samir Neogy, Indian Statistical Institute · Invited Session

Samir Neogy, Indian Statistical Institute

Generalized principal pivot transforms, complementarity problem and its applications in game theory

The notion of principal pivot transform (PPT) was introduced by Tucker and it is encountered in mathematical programming, complementarity problem, game theory, statistics, matrix analysis and many other areas. It is originally motivated by the well-known linear complementarity problem. In this talk, we discuss the concept of generalized principal pivot transform and present its properties and applications. The proposed generalized principal pivoting algorithm has many game theoretical applications. This generalized principal pivoting algorithm is a finite step algorithm and even in the worst case, this algorithm is partial enumeration only. It is demonstrated that computational burden reduces significantly for obtaining the optimal stationary strategies and value vector of the some structured stochastic game problem.

Abhijit Gupta, Indian Statistical Institute

Complementarity model for a mixture class of stochastic game

Researchers from the field of game theory adopted Lemke's approach to the field stochastic games and formulated the problem of computing the value vector and stationary strategies for many classes of structured stochastic game problem as a complementarity problem and obtain finite step algorithms for this special class of stochastic games. In this talk we consider a mixture class of zero-sum stochastic game in which the set of states are partitioned into sets S_1 , S_2 and S_3 so that the law of motion is controlled by Player I alone when the game is played in S_1 , Player II alone when the game is played in S_2 and in S_3 the reward and transition probabilities are additive. We obtain a complementarity model for this mixture class of stochastic game. This gives an alternative proof of the ordered field property that holds for such a mixture type of game. Finally we discuss about computation of value vector and optimal stationary strategies for discounted and undiscounted mixture class of stochastic game.

Arup Das, Indian Statistical Institute

A complementarity approach for solving two classes of undiscounted structured stochastic games

In this talk, we consider two classes of structured stochastic games, namely, undiscounted zero-sum switching controller stochastic games and undiscounted zero-sum additive reward and additive transitions (ARAT) games. Filar and Schultz observed that an undiscounted zero-sum stochastic game possesses optimal stationary strategies if and only if a global minimum with optimum value zero can be found to an appropriate linearly constrained nonlinear program. However, a more interesting problem is the reduction of these nonlinear programs to linear complementarity problems or linear programs. The problem of computing the value vector and optimal stationary strategies is formulated as a linear complementarity problem for these two classes of undiscounted zero-sum games. Implementation of available pivoting algorithms on these two formulations are also discussed.

Complementarity & variational inequalities

Wed.1.MA 313

Advances in the theory of complementarity and related problems I

Chair Chandrashekar Arumugasamy, Central University of Tamil Nadu

Jein-Shan Chen, National Taiwan Normal University (with Xinhe Miao)

Lipschitz continuity of solution mapping of symmetric cone complementarity problem

This paper investigates the Lipschitz continuity of the solution mapping of symmetric cone (linear or nonlinear) complementarity problems (SCLCP or SCCP, respectively) over Euclidean Jordan algebras. We show that if the transformation has uniform Cartesian P -property, then the solution mapping of the SCCP is Lipschitz continuous. Moreover, we establish that the monotonicity of mapping and the Lipschitz continuity of solutions of the SCLCP imply ultra P -property, which is a concept recently developed for linear transformations on Euclidean Jordan algebra. For a Lyapunov transformation, we prove that the strong monotonicity property, the ultra P -property, the Cartesian P -property and the Lipschitz continuity of the solutions are all equivalent to each other.

Alexey Kurennoy, Moscow State University (with Alexey Izmailov)

On regularity conditions for complementarity problems

In the context of mixed complementarity problems, various concepts of solution regularity are known, each of them playing a certain role in related theoretical and algorithmic developments. In this presentation, we provide the complete picture of relations between the most important regularity conditions for mixed complementarity problems. We not only summarize the existing results on the subject, but also establish some new relations filling all the gaps in the current understanding of how different types of regularity relate to each other. The regularity conditions to be considered include BD and CD regularities of the natural residual and Fischer-Burmeister reformulations, strong regularity, and semistability. A special attention is paid to the particular cases of a nonlinear complementarity problem and of a Karush-Kuhn-Tucker system.

Chandrashekar Arumugasamy, Central University of Tamil Nadu

Some new results on semidefinite linear complementarity problems

Given a linear transformation $L : S^n \rightarrow S^n$ and $Q \in S^n$, the semidefinite linear complementarity problem $SDLCP(L, Q)$ is to find an $X \in S_+^n$ such that $L(X) + Q \in S_+^n$ and $\langle X, L(X) + Q \rangle = 0$. Here S^n is the space of all real symmetric matrices of order n and S_+^n is the cone of all positive semidefinite matrices in S^n . This problem is considered as the natural generalization of the standard linear complementarity problem. One of the fundamental problem in $SDLCP$ is to characterize and identify linear transformations on S^n based on the properties of the solution sets. In this presentation we discuss some necessary and sufficient conditions on the linear transformation L to have non-empty compact solution sets for all $Q \in S^n$ to the problem $SDLCP(L, Q)$.

Conic programming

Wed.1.H 2036

New conic optimization approaches for max-cut and graph equipartition

Organizer/Chair Miguel Anjos, École Polytechnique de Montreal · Invited Session

Nathan Krislock, INRIA Grenoble Rhône-Alpes (with Jérôme Malick, Frédéric Roupin)

Improved semidefinite bounding procedure for solving max-cut problems to optimality

We present an improved algorithm for finding exact solutions to Max-Cut and the related binary quadratic programming problem, both classic problems of combinatorial optimization. The algorithm uses a branch-(and-cut)-and-bound paradigm, using standard valid inequalities and nonstandard semidefinite bounds. More specifically, we add a quadratic regularization term to the strengthened semidefinite relaxation in order to use a quasi-Newton method to compute the bounds. The ratio of the tightness of the bounds to the time required to compute them can be controlled by two real parameters; we show how adjusting these parameters and the set of strengthening inequalities gives us a very efficient bounding procedure. Embedding our bounding procedure in a generic branch-and-bound platform, we get a competitive algorithm: extensive experiments show that our algorithm dominates the best existing method.

Andreas Schmutzer, University of Cologne (with Miguel Anjos, Frauke Liers, Gregor Pardella)

Branch-and-cut for the graph 2-equipartition problem

A minimum 2-equipartition of an edge-weighted graph is a partition of the nodes of the graph into two sets of equal size such that the sum of the weights of edges joining nodes in different partitions is minimum. We compare basic linear and semidefinite relaxations for the

Constraint programming

equicut problem and find that linear bounds are competitive with the corresponding semidefinite ones but can be computed much faster. We further present detailed computational evaluations for a branch-and-cut algorithm using linear relaxations.

Angelika Wiegele, Alpen-Adria-Universität Klagenfurt (with Elspeth Adams, Miguel Anjos, Franz Rendl)
Lasserre hierarchy for max-cut from a computational point of view

The max-cut problem is one of the classical NP-complete problems defined on graphs. SDP-relaxations turned out to be in particular successful on these problems. Beside the basic semidefinite relaxation (underlying the Goemans-Williamson hyperplane rounding algorithm) and tightenings of this relaxation, iterative approaches exist that converge towards the cut polytope. Such a systematic hierarchy was introduced by Lasserre. The first relaxation in this hierarchy coincides with the basic SDP relaxation. Due to the high computational cost, already the second relaxation in this Lasserre-hierarchy is intractable for small graphs.

We present an iterative algorithm for computing a strengthened SDP-relaxation towards this second relaxation combined with constraints from the metric polytope. This can also be viewed as a strengthening of the basic SDP relaxation using semidefinite cuts. We present theoretical facts and report preliminary computational results.

Conic programming

Wed.1.H 2038

Conic and convex programming in statistics and signal processing II

Organizer/Chair Venkat Chandrasekaran, Caltech · Invited Session

Rachel Ward, University of Texas at Austin (with Deanna Needell)

Robust image recovery via total-variation minimization

Discrete images, composed of patches of slowly-varying pixel values, have sparse or compressible wavelet representations which allow the techniques from compressed sensing such as L1-minimization to be utilized. In addition, such images also have sparse or compressible discrete derivatives which motivate the use of total variation minimization for image reconstruction. Although image compression is a primary motivation for compressed sensing, stability results for total-variation minimization do not follow directly from the standard theory. In this talk, we present numerical studies showing the benefits of total variation approaches and provable near-optimal reconstruction guarantees for total-variation minimization using properties of the bivariate Haar transform.

Joel Tropp, California Institute of Technology (with Michael McCoy)

Sharp recovery bounds for convex deconvolution, with applications

Suppose we observe the sum of two structured signals, and we are asked to identify the two components in the mixture. This setup includes the problem of separating two signals that are sparse in different bases and the problem of separating a sparse matrix from a low-rank matrix. This talk describes a convex optimization framework for solving these deconvolution problems and others.

We present a randomized signal model that captures the idea of “incoherence” between two structures. The calculus of spherical integral geometry provides exact formulas that describe when the optimization problem will succeed (or fail) to deconvolve the component signals with high probability. This approach yields summary statistics that measure the complexity of a particular structured signal. The total complexity of the two signals is the only factor that affects whether deconvolution is possible.

We consider three stylized problems. (1) Separating two signals that are sparse in mutually incoherent bases. (2) Decoding spread-spectrum transmissions in the presence of impulsive noise. (3) Removing sparse corruptions from a low-rank matrix. In each case, the theory accurately predicts performance.

Parikshit Shah, University of Wisconsin (with Venkat Chandrasekaran)

Group symmetry and covariance regularization

Statistical models that possess symmetry arise in diverse settings such as random fields associated to geophysical phenomena, exchangeable processes in Bayesian statistics, and cyclostationary processes in engineering. We formalize the notion of a symmetric model via group invariance. We propose projection onto a group fixed point subspace as a fundamental way of regularizing covariance matrices in the high-dimensional regime. In terms of parameters associated to the group we derive precise rates of convergence of the regularized covariance matrix and demonstrate that significant statistical gains may be expected in terms of the sample complexity. We further explore the consequences of symmetry on related model-selection problems such as the learning of sparse covariance and inverse covariance matrices.

Wed.1.H 3003A

Modeling and reformulation

Organizer/Chair Mark Wallace, Monash University · Invited Session

Mark Wallace, Monash University (with Maria Garcia de la Banda, Chris Mears)

Inferring properties of models from properties of small instances

To solve large problem instances efficiently, expert modelers exploit properties of the problem (model) that enable specialised solving methods to be applied. Examples include symmetry-breaking, subproblem solution caching, introducing global constraints and other problem relaxations. The automation of this process is a research challenge with a potentially huge practical impact.

Unfortunately automated analysis of large problem instances is computationally very costly, so typically only “obvious” properties can be detected and exploited.

This paper presents an approach which uses automated analysis of small instances to infer properties of the problem model which can then be applied to solving large instances. To date the approach has been successfully applied to symmetries and caching, and its application to problem relaxations is the subject of our current research.

Helmut Simonis, University College Cork (with Nicolas Beldiceanu)

Building global constraint models from positive examples

We present a system which generates global constraint models from few positive examples of problem solutions. In contrast to previous constraint acquisition work, we present a novel approach based on the global constraint catalog and the Constraint Seeker tool which generates models for problems which can be expressed as regular conjunctions of similar constraints.

Our system first generates regular groupings of variables in the given samples. The Constraint Seeker is then used to find ranked, typical constraints which match all given positive examples. A dominance check, which removes implied constraints based on meta-data in the constraint catalog, leads to a final ranked set of candidate constraints for each problem.

The system is implemented in SICStus Prolog, and heavily relies on the constraint description and evaluators in the global constraint catalog. We show results for more than 200 example problems, ranging from puzzles to sports scheduling, placement and layout problems. The problems range from 4 to over 6000 variables, and use between one and 7000 samples, utilizing over 50 global constraints of the catalog. We achieve an overall hit-rate of about 50%.

Ian Miguel, University of St Andrews (with Ozgur Akgun, Alan Frisch, Brahim Hnich, Christopher Jefferson)

Towards automated constraint modelling with essence and conjure

Constraint solving offers an efficient means of solving a variety of combinatorial problems. A critical and well-recognised bottleneck in applying constraints is the formulation of an effective constraint model of a given problem. Without help, it is very difficult for a novice user to formulate an effective (or even correct) model. This can lead to very long solution times, or to incorrect solutions. Our approach to this problem, described in this talk, is to allow the user to describe a problem in the specification language Essence without committing to a constraint model. Using a set of refinement rules, this specification is then transformed automatically into a constraint model using our Conjure system. Our empirical results confirm that Conjure can reproduce successfully the kernels of the constraint models of benchmark problems found in the literature. Next steps include choosing among the models Conjure can produce, and adding automatically the embellishments human experts use to enhance the performance of their models, such as symmetry breaking and implied constraints.

Derivative-free & simulation-based opt.

Wed.1.H 3503

Exploiting structure in derivative-free optimization

Organizers/Chairs Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory · Invited Session

Carl Kelley, NC State University (with David Mokrauer)

Sparse interpolatory models for molecular dynamics

We describe a method for using interpolatory models to accurately and efficiently simulate molecular excitation and relaxation. We use sparse interpolation for efficiency and local error estimation and control for robustness and accuracy.

The objective of the project is to design an efficient algorithm for simulation of light-induced molecular transformations. The simulation seeks to follow the relaxation path of a molecule after excitation by light. The simulator is a predictive tool to see if light excitation and subse-

quent return to the unexcited or ground state will produce a different configuration than the initial one.

The goals of the simulation are not only to identify the end point, but to report the entire path in an high-dimensional configuration space so that one can look for nearby paths to interesting configurations and examine the energy landscape near the path to see if low energy barriers make jumping to a different path possible.

Warren Hare, UBC (with Mason Macklem, Julie Nutini)

Derivative free optimization for finite minimax functions

In this talk we consider derivative-free optimization for finite minimax problems; that is objective functions of the form $F = \max(f_i)$. We work under the assumption that each f_i is provided via an oracle function that is analytically unavailable. Commonly such problems are dealt with via smoothing techniques. In this talk we avoid smooth techniques that obscure the substructure of such functions and instead use the substructure to generate an approximate subdifferential. Techniques on robust subdifferentials are employed to further improve convergence. Convergence and some numerical results are presented.

Rommel Regis, Saint Joseph's University (with Stefan Wild)

A derivative-free trust-region algorithm for constrained, expensive black-box optimization using radial basis functions

This talk will present a derivative-free algorithm for constrained black-box optimization where the objective and constraint functions are computationally expensive. The proposed algorithm employs a trust-region framework that uses interpolating radial basis function (RBF) models for the objective and constraint functions and is an extension of the ORBIT algorithm. This algorithm will be compared with alternative methods on a series of test problems and on an automotive application with 124 decision variables and 68 black-box inequality constraints.

Finance & economics

Wed.1.H 3027

Price dynamics in energy markets

Organizer/Chair Florentina Paraschiv, IOR/CF University of St. Gallen - Invited Session

Péter Erdős, Swiss Institute of Banking and Finance, University of St. Gallen

Have oil and gas prices got separated?

Prices are driven by oil prices only if there is sufficient inter-fuel competition in the US, or if gas arbitrage is possible across the Atlantic. In the period 1994–2011 interfuel replacement was marginal in the US; therefore, the coupling of oil and gas prices depended on intercontinental trade movements. Until the end of 2008 the US depended on gas imports, contributing to higher average gas prices in the US than those in Europe and attracting export to the US. Thus, the Atlantic arbitrage, taking into account transaction costs, forced gas prices to converge in the US and in Europe in the long run. Since European gas prices react to price developments in the oil market, the Atlantic arbitrage also reinforced oil-gas linkage in the US. Since 2009 US oil and gas prices have decoupled due to limits to arbitrage across the Atlantic. Despite gas extraction from shale formations boosting the US gas inventories, which in turn depresses prices below the European level, US export is not viable because of a lack of liquefying infrastructure and administrative obstacles.

Michael Schuerle, University of St. Gallen (with Florentina Paraschiv)

Price dynamics in gas markets

Modeling natural gas futures prices is essential for valuation purposes as well as for hedging strategies in energy risk management. We present a general multi-factor affine diffusion model which incorporates the joint stylized features of both spot and futures prices. The model is brought into state space form on which Kalman Filter techniques are applied to evaluate the maximum likelihood function. We further build the basis for the construction of a daily gas price forward curve. These prices take into account the seasonal structures of spot prices and are consistent under the arbitrage-free condition with the observed market prices of standard products that provide gas delivery over longer periods. Finally the performance of the models is illustrated comparing historical and model implied price characteristics.

Florentina Paraschiv, IOR/CF University of St. Gallen

Modelling negative electricity prices

We evaluate different financial and time series models such as: mean reversion with jump processes, ARMA, GARCH usually applied for electricity price simulations. Since 2008 market design allows for negative prices at the European Energy Exchange (EEX), which occurred for several hours in the last decades. Up to now, only a few financial and time-series approaches exist, which are able to capture negative prices. We propose a new model for simulating energy spot prices taking into account their jumping and spiking behavior. The model parameters are calibrated using the historical hourly price forward curves for

EEX and Phelix, as well as the spot price dynamics. Parameters for the spikes which characterize the spot dynamics are derived on an hourly basis. Market clearing prices are derived given an observed price forward curve and an algorithm deciding whether a spike or a Poisson jump occurs.

Game theory

Wed.1.MA 005

Games over networks

Organizer/Chair Asu Ozdaglar, MIT - Invited Session

Asu Ozdaglar, MIT (with Daron Acemoglu, Azarakhsh Malekian)

Network security and contagion

This paper develops a network model of investments in security. The connections introduce the possibility of cascading failures. With exogenous attacks, a single attack takes place in one part of the network determined at random. Each agent chooses their level of security investment *ex ante* (before knowing where the attack will take place) according to a potentially-heterogeneous cost function. We establish existence of a pure-strategy equilibrium and provide conditions for its uniqueness, which require the cost functions for security investments to be sufficiently convex. Under the same conditions, the expected number of total infections will be lower in the social welfare maximum than in the equilibrium. Neither the uniqueness nor the efficiency result is true in general. With endogenous attacks, the attacker is modeled as choosing a probability distribution over the location of the attack. In contrast to the model with exogenous attacks, there is now an economic force for pervasive overinvestment in security. By increasing security investments, an agent discourages attacks to his part of the network, shifting the attack to other parts, and creating a negative externality.

Pablo Parrilo, Massachusetts Institute of Technology (with Ozan Candogan, Asuman Ozdaglar)

Near-potential network games

It is known that "natural" distributed dynamics such as best-response converge to an equilibrium only for restrictive classes of games, such as potential games. These considerations lead to natural and important questions: What makes potential games "special"? Can we approximately characterize the properties of a given network game, by analyzing a potential game that is close to it?

In this talk we provide an optimization-based framework for finding, and characterizing the properties, of the closest potential game to a given network game. We focus on both bilateral and multilateral interaction games, where the payoff of each agent can be written as a function of its neighbors' strategies. We show that the closest potential game to a multilateral interaction game is a second-order multilateral interaction game, i.e., a game where the payoff of each player is a function of strategies of its neighbors, and their neighbors. Our results indicate that a network game and the closest potential game have similar structural features, and these can be used to characterize static and dynamic properties of the original network game.

Ali Jadbabaie, University of Pennsylvania (with Arastoo Fazeli)

A game-theoretic model of competitive contagion and product adoption in social networks

We propose and analyze a strategic model of marketing and product adoption in social networks. Two firms compete for the spread of their products. Given a fixed budget, each firm has to decide how much to invest in their product and as a result, determine the payoff the customers get by adopting each firm's product, as well as the number of the initial seeds in the network. Once the payoff is determined, agents in the social network play a local coordination game over the network which determines the dynamics of the spreading. Assuming myopic best response dynamics, agents choose a product based on the received payoff (which depends on the firm's decision) by looking at actions of their neighbors. This local update dynamics results in a game-theoretic diffusion process in the network. We derive an explicit characterization of these bounds based on the payoff of products offered by firms, the initial number of adoptions and the underlying structure of the network. We then study the equilibrium of the game between firms and analyze the trade off between investment in product's quality vs. increasing the number of initial seeds.

Game theory

Wed.1.MA 043

Variational inequalities in games

Chair Vikas Jain, Jaypee University of Engineering and Technology

Evgeniy Gotshtein, CEMI RAS

Many-person games with convex structure

The set of Nash equilibrium points of a non-cooperative many-

person game coincides with the solution set of a variational inequality associated with this game. The game is said to have a convex structure if the above mentioned variational inequality is defined by a monotone mapping. The convex-structure games can be solved by efficient numerical methods. The paper presents a sufficient condition to guarantee a game to have a convex structure. For finite games in mixed strategies, the author gives an equivalent form of this condition in terms of the tables defining the game. Moreover, for the class of finite games, it is demonstrated that the proposed condition is not only sufficient but also necessary for the convex-structure games.

Vikas Jain, Jaypee University of Engineering and Technology

Constrained vector-valued dynamic game and symmetric duality for multiobjective variational problems

A certain constrained vector-valued dynamic game is formulated and shown to be equivalent to a pair of multiobjective symmetric dual variational problems which have more general formulations than those studied earlier. A number of duality theorems, are established under suitable generalized convexity assumptions on the functionals. This constrained vector-valued dynamic game is also regarded as equivalent to a pair of symmetric multiobjective dual variational problems with natural boundary conditions rather than fixed end points. Finally, it is also indicated that our results can be considered as dynamic generalization of those already studied in the literature.

Global optimization

Wed.1.H 2053

Optimal hybrid control theory approaches to global optimization

Organizer/Chair Zelda Zabinsky, University of Washington · Invited Session

Zelda Zabinsky, University of Washington (with Wolf Kohn)

Solving non-linear discrete optimization problems via continualization: An interior-point algorithm

Continuous optimization problems have a tremendous structural advantage over discrete optimization problems: continuity. Necessary conditions for optimality are expressed in terms of differentiability, convexity, and other structural properties. This makes developing algorithms for continuous problems an easier task than for discrete problems. In this talk, we present a continualization approach for transforming discrete optimization problems into a continuous formulation over a compact domain. The target formulation is amenable to an interior-point descent algorithm. We use a conditional sampling procedure to translate solutions of the continuous problem into approximate solutions of the original discrete problem. The interior-point descent algorithm is expressed by a set of coupled differential equations whose integration via numerical methods generates approximate solutions to the original problem in polynomial time. The continuous problem can be characterized by a variational formulation. The central element of this formulation is a Lagrangian with nonsingular Hessian. This leads to the differential equations in the descent algorithm.

Wolf Kohn, University of Washington (with Zelda Zabinsky)

Hybrid dynamic programming for rule constrained multi-objective optimization

Many optimization problems associated with large-scale complex systems require a model definition that is almost impossible to specify completely. Further, real-world applications must evaluate trade-offs between multiple objectives, which demands set representation. We will present some preliminary results of our research on developing an optimal feedback control paradigm for solving optimization problems with multiple objectives in which the model defined by the constraints is incomplete, and a complete description of the system is not available. Our optimization paradigm includes active learning of the structure of the model that goes beyond parameter adaptation. The constraints include, algebraic relations, operational if-then rules, discrete- and continuous-time dynamics, and sensor-defined constraints. Our modeling approach is based on the theory of dynamic set inclusion, because this theory lends itself to construct efficient algorithms that include learning mechanisms. Our strategy is to convert all the constraints characterizing the model to continuous-time set dynamics using a continualization transformation developed in a previous paper by Kohn, et al.

Pengbo Zhang, University of Washington

Stochastic control optimization of a binary integer program

We develop a discrete meta-control algorithm that provides a good approximation to large-scale binary integer programs with low polynomial time complexity. The key innovation to our optimal control approach is to map the vector of n binary decision variables into a scalar function defined over a discrete time interval $[0, n]$ and define a linear quadratic tracking (LQT) problem that closely approximates the original problem. Our method uses an Aoki-based decomposition approach

and an error correction with a Kalman filter technique that introduces less error than the continuous form used in our previous research, but maintains the primary computational advantage. We use the necessary conditions for optimality to prove that there exists an integer solution to the LQT version of the original BIP, with a bang-bang type solution. We prove that our meta-control algorithm converges to an approximate solution in polynomial time with regard to the time horizon, which is the number of binary variables n . The algorithm is illustrated with several large examples. The meta-control algorithm can be extended to mixed integer programs.

Implementations & software

Wed.1.H 1058

Implementations of interior point methods for linear and conic optimization problems

Organizer/Chair Erling Andersen, MOSEK ApS · Invited Session

Csaba Meszaros, MTA SZTAKI

Exploiting hardware capabilities in implementations of interior point methods

The talk concerns the implementation of interior point methods for solving large-scale optimization problems. In our investigation we focus on the exploitation of the recently introduced AVX vector instruction set and show that the capabilities of modern processors can be highly exploited by special implementation techniques. We describe the implementation design of our interior point solver and demonstrate that its performance on standard multi-core platforms can reach 100 Gflops when solving large-scale optimization problems.

Erling Andersen, MOSEK ApS

On recent improvements in the interior-point optimizer in MOSEK

In this talk we will discuss the recent advances in the interior-point optimizer in the upcoming version 7 release of MOSEK. The advances include better dense column handling, an improved GP ordering for the normal equations, handling of intersection cones and warmstart capabilities. Beyond these advances the interior-point optimizer has also been extended to handle semi-definite optimization problems.

Imre Polik, SAS Institute (with Philipp Christophel)

Crossing over

There are only few academic papers about crossover techniques, i.e., about algorithms that take an optimal solution of an LP and "round" it to an optimal basic solution. Moreover, the problem we face in practice is very different from the setup in these papers. In this talk we wish to highlight these differences and offer new techniques for the different problems. Besides the standard case of interior-point methods, other issues we are discussing are solutions from the network simplex method, basic infeasibility and unboundedness certificates, and perturbation techniques. Computational experiments using SAS/OR will be presented.

Integer & mixed-integer programming

Wed.1.H 1013

Scheduling I

Chair Andrea Raith, The University of Auckland

Hesham Alfarees, King Fahd University of Petroleum & Minerals

Integer programming model and optimum solution for a bi-objective days-off scheduling problem

An integer programming model and optimal solution procedure are presented for a real-life cyclic day-off scheduling problem. Efficient techniques are used to determine the best assignment of employees to the (10, 14) days-off schedule. This special work schedule, involving ten consecutive workdays in a two-week cycle, is used by a large oil company to schedule employees in remote work locations. The primary objective is to minimize the total number of employees, and the secondary objective is to minimize the total number of active days-off work patterns. Two days-off scheduling rules are enforced: a minimum proportion of weekend days off needs to be given, and a maximum limit on the number of successive work days cannot be exceeded. Primal-dual relationships are used to identify dominant solutions and to determine the minimum workforce size. Utilizing the problem structure and real-life parameter values, simple optimal procedures are developed to determine the minimum number of days-off patterns and the number of employees assigned to each pattern. A rotation scheme is used to en-

sure sufficient weekend off days are given and work stretch limits are not exceeded.

Andy Felt, UW-Stevens Point (with Eli Towle)

MILP model for athletic conference scheduling

We examine a MILP model used for determining the specific dates and locations for athletic conference match ups given predetermined available dates and teams. The model takes into account home/away game equivalency, the number of consecutive home/away games, as well as any other stipulations requested by the conference. It accommodates multiple sports spanning multiple seasons. Such models have been utilized by the UWSP Center for Athletic Scheduling to generate optimal schedules for NCAA Division-III athletic conferences adhering to the given constraints.

Andrea Raith, The University of Auckland (with Amelia White)

Minimising tardiness in parallel machine scheduling with setup times and mould type restrictions

We study a parallel machine scheduling problem with sequence-dependent setup time. The jobs in this machine-scheduling problem have due dates and each job is of a particular job family. Each job family requires a specific mould to be installed on the machine for production. The setup time of the moulds is significant and there is only a small number of each type of mould available. We present preliminary results of our research into this problem. We propose a time-indexed integer programming formulation that minimises overall job tardiness. The formulation has constraints that model both setup times of the moulds and constraints that restrict the number of machines that can produce jobs of the same family at the same time due to limited availability of moulds. We show that some of the constraints can be relaxed and that the obtained optimal solutions of the relaxed problem can be post-processed to derive optimal mould-feasible solutions thus speeding up computation time. We give an indication of expected running times for some test problem instances.

Integer & mixed-integer programming

Wed.1.H 2032

Trends in mixed integer programming IV

Organizers/Chairs Robert Weismantel, ETH Zurich; Andrea Lodi, University of Bologna · Invited Session

François Soumis, Polytechnique Montréal (with Issmail Elhallaoui, Abdelouahab Zaghrouti)

Integral simplex using decomposition

Since the early '70s, several authors proposed, without much success, adaptations of the simplex algorithm to reach an optimal integer solution to the set-partitioning problem, with a sequence of basic integer solutions. We present an algorithm that iteratively finds improving integer solutions up to optimality. The algorithm identifies the negative reduce cost columns producing integer pivots. If it has no more of these columns the algorithm solves a subproblem identifying a small group of columns to pivot in the base to reach a better integer solution. These two procedures permit to reach an optimal solution. Theoretical background and experimental results on problems up to 1600 constraints and 500 000 variables are presented. The larger problems are solved in time between 10 and 20 minutes.

Enrico Malaguti, DEIS – University of Bologna (with Fabio Furini)

Algorithms for 2-dimensional 2-staged guillotine cutting stock problems

Given a set of rectangular items classes with an associated positive demand and infinitely many identical rectangular bins, the 2-dimensional cutting stock problem requires cutting all the items by using the minimum number of bins or, equivalently, by minimizing the global area of the used bins. We consider the 2-dimensional 2-staged guillotine cutting stock problem, where items must be obtained through at most two stages of guillotine cuts (we allow trimming, i.e., a third stage cut can be used to separate a rectangle from a waste area). The problem is a generalization of the corresponding 2-dimensional bin packing problem, where the demand is equal to 1 for all the item classes. In this talk we describe a branch-and-price algorithm for the problem, and discuss the adaptation of generic branching rules to the specific case. In addition, we extend a compact integer linear programming model from the literature, proposed for the bin packing case, to the more general cutting stock problem. The performance of the proposed models and solution algorithms is evaluated through computational experiments on a set of benchmark instances from the literature.

Friedrich Eisenbrand, TU Berlin (with Dömötör Pálvolgyi, Thomas Rothvoß)

On bin packing, the MIRUP conjecture and discrepancy theory

Bin packing a classical combinatorial optimization problems for which the development of approximation algorithms and integer programming methods is an impressive success story. Yet, a prominent

problem related to bin-packing is still open: Is there an OPT+1 approximation algorithm and does the column-generation ILP of Gilmore and Gomory have a constant additive integrality gap?

In this talk, I survey some recent results around this open problem that deal with a relationship of approximation algorithms for bin packing and discrepancy theory. In particular, I describe the limits of LP-rounding for bin packing that are implied by a recent lower bound on the discrepancy of three permutations by Newman and Nikolov.

Integer & mixed-integer programming

Wed.1.H 2033

Assignments and partitioning

Chair Trivikram Dokka, Katholieke Universiteit Leuven

Ya Ju Fan, Lawrence Livermore National Lab (with Chandrika Kamath)

A heuristic for the local region covering problem

The topological or local dimension of a data manifold can be obtained using local methods, where the data are divided into smaller regions. The original Fukunaga-Olsen algorithm for the intrinsic dimension of a dataset used heuristic approaches to identify the smaller regions. To obtain an improved partitioning of the data space, we formulate this problem as a set covering problem, where each local region contains the k nearest neighbors of a data point. We discuss how we define the cost function to obtain an estimation based on a fair selection of local regions. This problem can be seen as a facility location problem with the number of facilities being optimized in order to maintain the service to at most k cities per facility. To solve the local region problem, we present a simple and easy to implement heuristic method that is a variant of a greedy approach.

Trivikram Dokka, Katholieke Universiteit Leuven (with Ioannis Mourtos, Frits Spijksma)

Fast separation algorithms for multi-dimensional assignment problems

In polyhedral combinatorics, the polytope related to a combinatorial optimization problem is examined in order to obtain families of strong valid inequalities or, even better, to find inequalities that are facet-defining for this polytope. To incorporate such families of inequalities within a 'branch & cut' algorithm requires one further step: that of deriving an algorithm which determines whether an inequality of a specific family is violated by a given vector (the separation problem). The idea put forward in this work is to consider a compact representation of the given vector, and measure the complexity of a separation algorithm in terms of this compact representation. We illustrate this idea on the separation problem of well-known families of inequalities associated to the (multi-index) assignment polytope, and we show that for these families of inequalities better time-complexities than the current ones are possible.

Logistics, traffic, and transportation

Wed.1.H 0106

Vehicle routing and logistics optimization

Organizer/Chair Daniele Vigo, University of Bologna · Invited Session

Mario Ruthmair, Vienna University of Technology (with Günther Raidl)

An adaptive layers framework for vehicle routing problems

Current exact solution methods for vehicle routing problems are mostly based on set partitioning formulations enhanced by strong valid inequalities. We present a different approach where resources, e.g., capacities or times, are modeled on a layered graph in which the original graph is duplicated for each achievable resource value. MIP models on this layered graph typically yield tight LP bounds. However, as the size of this graph strongly depends on the resource bounds, such models may be huge and impracticable. We propose a framework for approximating the LP bound of such a resource-indexed formulation by a sequence of much smaller models. Based on a strongly reduced node set in the layered graph we redirect arcs in a way to obtain lower and upper bounds to the LP value of the complete model. This reduced layered graph is iteratively extended, decreasing the gap. Moreover, a sequence of improving primal bounds can be provided. The final model extended by inequalities to ensure feasibility is solved by branch-and-cut. Obtained results, e.g., for the vehicle routing problem with time windows, look promising although we currently cannot compete with state-of-the-art methods.

Roberto Roberti, University of Bologna (with Roberto Baldacci, Aristide Mingozzi)

Dynamic NG-path relaxation

We recently introduced a new state-space relaxation, called ng -path relaxation, to compute lower bounds to routing problems. This relaxation consists of partitioning the set of all possible paths ending at a

generic vertex according to a mapping function that associates with each path a subset of the visited vertices that depends on the order in which such vertices are visited.

In this talk, we propose a new dynamic method to improve the *ng*-path relaxation which consists of defining, iteratively, the mapping function of the *ng*-path relaxation using the results achieved at the previous iteration. This method is analogous to cutting plane methods, where the cuts violated by the *ng*-paths at a given iteration are incorporated in the new *ng*-path relaxation at the next iteration.

The new technique has been used to solve the traveling salesman problem with cumulative costs (CTSP) and to produce new benchmark results for the TSPTW. The results obtained show the effectiveness of the proposed method.

Daniele Vigo, University of Bologna (with Maria Battarra, Gunes Erdogan)

An exact approach for the clustered vehicle routing problem

We present an exact approach for the clustered vehicle routing problem (Clu-VRP), which is a generalization of the capacitated vehicle routing problem (CVRP), in which the customers are grouped into clusters. As in the CVRP, all the customers must be visited exactly once, but a vehicle visiting one customer in a cluster must visit all the remaining customers in the cluster before leaving it. An integer programming formulation for the Clu-VRP based on an exponential time preprocessing scheme is presented. The linear relaxation of the formulation is strengthened in a branch & cut algorithm by including valid inequalities for the CVRP. Computational experiments on instances adapted from the literature and real-world problems are presented.

Logistics, traffic, and transportation

Wed.1.H 0111

Stochastic routing

Organizer/Chair Pieter Audenaert, Ghent University – IBBT · Invited Session

Sofie Demeyer, Ghent University (with Pieter Audenaert, Mario Pickavet)

Time-dependent stochastic routing: A practical implementation

By tracking cell phones and GPS systems on road networks, vast amounts of accurate travel time data can be collected. From this data we can derive time-dependent travel time probability distributions for each of the roads and by making use of these distributions, the travel time distribution of whole routes can be calculated. Here, we present a case study of an industrial-strength time-dependent and stochastic routing system, with the main focus on its practical implementation. Distributions are represented by a number of percentiles, since we use actual measured data and we do not want to impose a single common probability distribution. As determining the exact correlations between each pair of links is quite cumbersome, two extreme cases were investigated, namely assuming that all links are completely correlated and assuming they are not. A stochastic routing algorithm was developed that determines the travel time distribution in both cases. Experiments show that the resulting routes indeed are faster than those in a deterministic routing system. It should be noted that results of this work are deployed by the industrial partners involved in this research.

Moritz Kobitzsch, Karlsruhe Institute of Technology

Alternative routes and route corridors

We present an overview over two static route planning techniques, alternative routes and corridor graphs, and discuss how to compute them efficiently. An alternative route is considered a valid alternative to a shortest path, whenever it fulfils three simple criteria: local optimality, limited overlap, limited stretch. The second technique, corridor graphs, is a method to iteratively grow a subgraph around an initial set of paths to a single target. This technique bases on allowing deviations along the route and can account for minor detours. We expect a combination of these techniques to manifest itself in an immense reduction of the input size for stochastic route planning.

Sebastien Blandin, IBM Research Collaboratory - Singapore (with Alexandre Bayen, Samitha Samaranyake)

Fast computation of solution to stochastic on-time arrival problem

We consider the stochastic on-time arrival (SOTA) problem which consists in finding a policy that maximizes the probability of reaching a destination within a given budget. We propose novel algorithmic methods for the fast computation of its solution in general graphs with stochastic and strictly positive minimal network-wide edge weights, with application to transportation networks in particular. Our first contribution is based on the proof of existence of an optimal order for minimizing the computation time of the optimal policy for the SOTA problem in a dynamic programming framework. The second contribution of this work is based on the integration of a zero-delay convolution method, which allows for further reduction of the algorithm complexity by a factor $\log n/n$. We illustrate the comparative run-times of the different algorithms on selected synthetic networks and on actual road networks

from Northern California, using real travel-time estimates from the Mobile Millennium traffic information system.

Mixed-integer nonlinear programming

Wed.1.MA 042

Topics in mixed-integer nonlinear programming I

Chair Anita Schöbel, Georg-August Universität Göttingen

Laura Galli, University of Warwick (with Adam Letchford)

Reformulating mixed-integer quadratically constrained quadratic programs

It is well known that semidefinite programming (SDP) can be used to derive useful relaxations for a variety of optimisation problems. Moreover, in the particular case of mixed-integer quadratic programs, SDP has been used to reformulate problems, rather than merely relax them. In two recent papers, Billionnet et al. (2009), (2012) present their reformulation method, which they call Quadratic Convex Reformulation (QCR), and apply it respectively to equality-constrained 0–1 QP and general mixed-integer QP (MIQP). In their second paper (2012), they use binary expansion to convert bounded integer quadratic instances into 0–1 QP. We show that binary expansion never causes the SDP bound to get any worse and sometimes can lead to an improvement. Then we show that, under certain conditions, the QCR method can be extended to the even more general case of mixed-integer quadratically constrained quadratic programming (MIQCQP). Handling quadratic constraints turns out to be a non-trivial exercise. In our computational results we implement different reformulation schemes and compare the corresponding bounds.

Yi-Shuai Niu, CNRS - French National Center for Scientific Research (with Tao Pham Dinh)

On combination of DCA branch-and-bound and DC-Cut for solving mixed-01 linear programs

We propose a new hybrid approach based on DC (Difference of convex functions) programming and DCA (DC algorithm) with combination of Branch-and-Bound (BB) framework and new local cutting plan technique (DC-Cut) for globally solving mixed-01 linear program. We will firstly reformulate a mixed-integer linear program as a DC program via exact penalty technique, then an efficient local optimization algorithm DCA is proposed for searching upper bound solutions. The new DC-Cut technique can construct cutting plans from some integer and non-integer local minimizers of DC program which helps to reduce the feasible set and accelerate the convergence of BB. This algorithm can be naturally extended for mixed-01 nonlinear program. Preliminary numerical results comparing with some existing methods will be reported.

Anita Schöbel, Georg-August Universität Göttingen (with Daniel Scholz)

A geometric branch and bound approach for nonlinear mixed-integer optimization

Geometric branch-and-bound techniques are popular solution algorithms for continuous, non-convex global optimization problems. The most important task throughout these algorithms is the calculation of good lower bounds on the objective function. Several techniques to do so exist. They can be compared theoretically by their rate of convergence.

The aim of this talk is to extend these geometric branch-and-bound methods to mixed integer nonlinear optimization problems, i.e. to objective functions with some continuous and some combinatorial variables. The idea is to do a geometric branching for the continuous variables and to approximate the remaining discrete problem in order to obtain the required bounds. This is in contrast to the classical integer branch-and-bound in which branching is done on the discrete variables.

We derive several bounding operations and theoretical results about their rate of convergence. Moreover, we discuss an extension of the method which leads to exact optimal solutions under certain conditions. The suggested techniques are applied to some mixed-integer facility location problems in which we succeed in finding exact optimal solutions.

Multi-objective optimization

Wed.1.H 1029

Vector optimization: Post pareto analysis

Organizer/Chair Henri Bonnet, University of New Caledonia · Invited Session

Jacqueline Morgan, University of Naples Federico II (with Henri Bonnet)

Semivectorial bilevel convex optimal control problems: Existence results

We consider a bilevel optimal control problem where the upper level, to be solved by a leader, is a scalar optimal control problem and the lower level, to be solved by several followers, is a multiobjective convex optimal control problem. We deal with the so-called optimistic case, when the followers are assumed to choose a best choice for the leader

among their best responses, as well with the so-called pessimistic case, when the best response chosen by the followers can be the worst choice for the leader. We present sufficient conditions on the data for existence of solutions to both the optimistic and pessimistic optimal control problems, with particular attention to the linear-quadratic case.

Henri Bonnel, University of New Caledonia (with Jacqueline Morgan)

Semivectorial bilevel optimal control problems: Optimality conditions

We deal with a bilevel optimal control problem where the upper level is a scalar optimal control problem to be solved by the leader, and the lower level is a multi-objective convex optimal control problem to be solved by several followers acting in a cooperative way inside the greatest coalition and choosing amongst the Pareto optimal controls. This problem belongs to post-Pareto analysis area because generalizes the problem of optimizing a scalar function over a Pareto set. We obtain optimality conditions for the so-called optimistic case when the followers choose among their best responses one which is a best choice for the follower, as well as for the so-called pessimistic case, when the best response chosen by the followers can be the worst case for the leader.

Julien Collonge, University of New-Caledonia (with Henri Bonnel)

Optimization over the Pareto set associated with a multi-objective stochastic convex optimization problem

We deal with the problem of minimizing the expectation of a scalar valued function over the Pareto set associated with a multi-objective stochastic convex optimization problem. Every objective is an expectation and will be approached by a sample average approximation function (SAA-N), where N is the sample size. In order to show that the Hausdorff distance between the SAA-N weakly Pareto set and the true weakly Pareto set converges to zero almost surely as N goes to infinity, we need to assume that all the objectives are strictly convex. Then we show that every cluster point of any sequence of SAA-N optimal solutions ($N = 1, 2, \dots$) is a true optimal solution. To weaken the strict convexity hypothesis to convexity, we need to work in the outcome space. Then, under some reasonable and suitable assumptions, we obtain the same type of results for the image of the Pareto sets. Thus, assuming that the function to minimize over the true Pareto set is expressed as a function of other objectives, we show that the sequence of SAA-N optimal values ($N = 1, 2, \dots$) converges almost surely to the true optimal value. A numerical example is presented.

Nonlinear programming

Wed.1.H 0107

Regularization techniques in optimization I

Organizer/Chair Jacek Gondzio, University of Edinburgh · Invited Session

Jacek Gondzio, University of Edinburgh

Recent advances in the matrix-free interior point method

The matrix-free interior point method allows for solving very large optimization problems without the need to have them explicitly formulated. The method uses problem matrices only as *operators* to deliver the results of matrix-vector multiplications. Recent advances including the new theoretical insights and the new computational results will be presented.

Paul Armand, XLIM Research Institute – University of Limoges (with Joël Benoist)

A boundedness property of the Jacobian matrix arising in regularized interior-point methods

We present a uniform boundedness property of a sequence of inverses of Jacobian matrices that arises in regularized primal-dual interior-point methods in linear and nonlinear programming. We then show how this new result can be applied to the analysis of the global convergence properties of these methods. In particular, we will detail the convergence analysis of an interior point method to solve nonlinear optimization problems, with dynamic updates of the barrier parameter.

Michael Saunders, Stanford University (with Christopher Maes)

QPBLUR: A regularized active-set method for sparse convex quadratic programming

QPBLUR is designed for large convex quadratic programs with many degrees of freedom. (Such QPs have many variables but relatively few active constraints at a solution, and cannot be solved efficiently by null-space methods.) QPBLUR complements SQOPT as a solver for the subproblems arising in the quasi-Newton SQP optimizer SNOPT.

QPBLUR uses a BCL algorithm [bound-constrained augmented Lagrangian] to solve a given QP. For each BCL subproblem, an active-set method solves a large KKT system at each iteration, using sparse LU factors of an initial KKT matrix and block-LU updates for a series of active-set changes. Primal and dual regularization ensures that the KKT systems are always nonsingular, thus simplifying implementation and permitting warm starts from any starting point and any active set. There

is no need to control the inertia of the KKT systems, and a simple step-length procedure may be used without risk of cycling in the presence of degeneracy.

We present the main features of QPBLUR and some numerical results from the Fortran 95 implementation on a test set of large convex QPs and on the QPs arising within SNOPT.

Nonlinear programming

Wed.1.H 0110

Trust-region methods and nonlinear programming

Organizers/Chairs Henry Wolkowicz, University of Waterloo; Ting Kei Pong, University of Waterloo · Invited Session

Ya-xiang Yuan, Chinese Academy of Sciences (with Xiaojun Chen, Lingfeng Niu)

Optimality conditions and smoothing trust region newton method for non-lipschitz optimization

Regularized minimization problems with nonconvex, nonsmooth, perhaps non-Lipschitz penalty functions have attracted considerable attention in recent years, owing to their wide applications in image restoration, signal reconstruction and variable selection. In this paper, we derive affine-scaled second order necessary and sufficient conditions for local minimizers of such minimization problems. Moreover, we propose a global convergent smoothing trust region Newton method which can find a point satisfying the affine-scaled second order necessary optimality condition from any starting point. Numerical examples are given to illustrate the efficiency of the optimality conditions and the smoothing trust region Newton method.

Ting Kei Pong, University of Waterloo (with Henry Wolkowicz)

Generalized trust region subproblem: Analysis and algorithm

The trust region subproblem (TRS) is the minimization of a (possibly nonconvex) quadratic function over a ball. It is the main step of the trust region method for unconstrained optimization, and is a basic tool for regularization. In this talk, we consider a generalization of the TRS, where the ball constraint is replaced by a general quadratic constraint with both upper and lower bounds. We characterize optimality under a mild constraint qualification and extend an efficient algorithm for TRS proposed by Rendl and Wolkowicz to this setting.

Yuen-Lam Vris Cheung, University of Waterloo (with Forbes Burkowski, Henry Wolkowicz)

Solving a class of quadratically constrained semidefinite programming problems with application to structure based drug design problem

We consider a class of quadratically constrained semidefinite programming (SDP) problems arising from a structure based drug design problem.

In graph theoretical terms, we aim at finding a realization of a graph with fixed-length edges, such that the sum of the distances between some of the non-adjacent vertices is minimized and the graph is realized in a Euclidean space of prescribed dimension. This problem can be seen as a Euclidean distance matrix completion problem and can be phrased as a semidefinite programming problem (SDP) with quadratic constraints. In order to provide approximate solutions to the special class of quadratically constrained SDP problems, we extend the techniques for solving two trust region problems (TTRS) and indefinite trust region problems to the SDP. We also present some preliminary numerical results on the structure based drug design problem.

Nonlinear programming

Wed.1.H 0112

Solution methods for matrix, polynomial, and tensor optimization

Organizer/Chair Shuzhong Zhang, University of Minnesota · Invited Session

Xin Liu, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (with Yin Zhang)

Beyond heuristics: Applying alternating direction method of multiplier method in solving matrix factorization problems

Alternating direction method of multiplier (ADMM) applies alternating technique on the KKT system of augmented Lagrangian function, which is a powerful algorithm for optimization problems with linear equality constraints and certain separable structures. However, its convergence has not been established except in two blocks, separable and convex cases.

In this talk, we will show ADMM also has excellent performances in solving some matrix factorization problems in which either separability or convexity does not apply. Furthermore we will present some preliminary results on the convergence of ADMM in these cases.

Zhening Li, Shanghai University (with Bitian Chen, Simai He, Shuzhong Zhang)

Maximum block improvement and polynomial optimization

We propose an efficient method for solving a large class of polyno-

mial optimization problems, in particular, the spherically constrained homogeneous polynomial optimization. The new approach has the following three main ingredients. First, we establish a block coordinate descent type search method for nonlinear optimization, with the novelty being that we accept only a block update that achieves the maximum improvement, hence the name of our new search method: maximum block improvement (MBI). Convergence of the sequence produced by the MBI method to a stationary point is proved. Second, we establish that maximizing a homogeneous polynomial over a sphere is equivalent to its tensor relaxation problem; thus we can maximize a homogeneous polynomial over a sphere by its tensor relaxation via the MBI approach. Third, we propose a scheme to reach a KKT point of the polynomial optimization, provided that a stationary solution for the relaxed tensor problem is available. Numerical experiments have shown that our new method works very efficiently: For a majority of the test instances that we have experimented with, the method finds the global optimal solution at a low computational cost.

Zheng-Hai Huang, Tianjin University (with Xianjun Shi, Lei Yang)

An iterative algorithm for tensor n -rank minimization

Tensor arises in many areas of science and engineering including data mining, machine learning and computer vision. In this talk, we consider the tensor n -rank minimization problem and adopt twice tractable convex relaxations to transform it into a convex, unconstrained optimization problem. Based on Fixed Point Continuation with Approximate Singular Value Decomposition, we propose an iterative algorithm for solving this class of problems. We show that the proposed algorithm is globally convergent under mild assumptions. The preliminary numerical results demonstrate that the proposed algorithm is effective, especially for the large-sized problems.

Nonsmooth optimization

Wed.1.H 1012

Recent advances in optimization methods

Organizer/Chair Marc Teboulle, Tel Aviv University · Invited Session

Jérôme Bolte, Toulouse School of Economics

Forward-backward splitting and other descent methods for semi-algebraic minimization problems

In view of the minimization of a nonsmooth nonconvex function of the form $f + g$ (where f is smooth semi-algebraic and g is lsc semi-algebraic), we present an abstract convergence result for descent methods which covers in particular the case of forward-backward splitting methods. Our result guarantees the convergence of bounded sequences, under the assumption that the function f satisfies the Kurdyka-Łojasiewicz inequality (KL inequality). This result applies to a wide range of problems, including nonsmooth semi-algebraic (i.e., polynomial-like) problems but also to analytic-like or more generally to the so-called *tame problems*. In this talk we shall emphasize on the following facts:

- the verifiability of the assumptions and the ubiquity of KL inequality
- the flexibility of the abstract result and its impact on the understanding of widely used methods.

Amir Beck, Technion – Israel Institute of Technology

The 2-coordinate descent method for solving double-sided simplex constrained minimization problems

This talk considers the problem of minimizing a smooth function subject to a single linear equality constraint and additional bound constraints on the decision variables. We introduce and analyze several variants of a 2-coordinate descent method – a block descent method that performs an optimization step with respect to only two variables at each iteration. Based on two new optimality measures, we establish convergence to stationarity points for general nonconvex objective functions. In the convex case, when all the variables are lower bounded but not upper bounded, we show that the sequence of function values converges at a sublinear rate.

Marc Teboulle, Tel Aviv University (with Amir Beck)

Nonsmooth convex minimization: To smooth or not to smooth?

Well known smoothing approaches tackling nonsmooth optimization problems via algorithms applied to their smoothed counterparts only provide an ε -optimal solution to the *approximated* smoothed problem. In this talk, we prove that independently of the structure of the function to be minimized, and of a given fast first order iterative scheme, by solving an adequately smoothed approximation, the original nonsmooth problem can be solved with an $O(\varepsilon^{-1})$ efficiency estimate. Our approach allows for clarification and unification to several issues on the design, analysis, and the potential applications of smoothing methods when combined with fast first order algorithms, and eventually answer to the question posed in the title!

Optimization in energy systems

Wed.1.MA 549

Games, energy and investment

Organizer/Chair Rene Aid, EDF R&D · Invited Session

Vincent Leclère, Ecole des Ponts ParisTech (with Matheus Grasselli, Mike Ludkovski)

The priority option: The value of being a leader in complete and incomplete markets

In a recent paper, Bensoussan, Diltz and Hoe (2010) provide a comprehensive analysis of optimal investment strategies under uncertainty and competition. They consider two firms competing for a project whose payoff can be either a lump-sum or a series of cash-flows, in both complete and incomplete markets. Despite its generality, the analysis is restricted to a Stackelberg game, where the roles of leader and follower are predetermined. In this talk, I'll extend the analysis to the case where these roles emerge as the result of a symmetric, Markov, sub-game perfect equilibrium, extending the seminal work of Grenadier (1996) and (2000) to incomplete markets. As a result, one can calculate the amount of money that a firm would be willing to spend in advance (either by paying a license or acquiring market power) to have the right to be the leader in a subsequent game – what we call the priority option.

Xiaolu Tan, CMAP, Ecole Polytechnique

A splitting scheme for degenerate nonlinear PDEs: Application in an optimal hydropower management problem

Based on the semi-Lagrangian scheme and the probabilistic scheme of Fahim, Touzi and Warin for non-degenerate fully nonlinear parabolic PDEs, we propose a splitting numerical method for degenerate nonlinear parabolic PDEs. We also provide a simulation-regression method to make the splitting scheme implementable. General convergence as well as rate of convergence are obtained under reasonable conditions, using the monotone convergence of viscosity solution techniques. Finally, we study an optimal hydropower management problem which can be characterized by a degenerate nonlinear parabolic PDE. A numerical resolution is given by this splitting method.

Imen Ben Tahar, Université Paris Dauphine

Integration of an intermittent energy: A mean fields game approach

The integration of renewable sources of energy to the grid brings new challenges, due to their intermittent nature. In this talk we propose a toy model, based on a mean fields games (MFG) approach, to analyze consumption decisions integrating a stochastic source of energy

Optimization in energy systems

Wed.1.MA 550

Optimization in the oil & natural gas industry

Organizers/Chairs Bruno Flach, IBM Research - Brazil; Luiz Barroso, PSR · Invited Session

Jorge Zubelli, IMPA (with Vincent Guigues, Claudia Sagastizabal)

Evaluation of LNG contracts with cancellation options

For gas companies, liquefied natural gas (LNG) appears as a convenient complement to their own natural gas resources. A proper mix of natural gas and LNG contracts allows a gas company not only to diversify its portfolio, but to better hedge risk. In the gas sector, risk concerns are related to volatility of gas prices and also to the obligation of providing a faultless delivery, especially to “uninterruptible” clients, usually crucial customers for the business.

LNG contracts offer the possibility to ship LNG loads at dates and volumes specified in the contract. Each shipment can be totally or partly cancelled, possibly paying a fee. Cancellation fees naturally increase as the shipment forecasted date approaches. Therefore, for a given LNG contract it is important to determine which loads might be cancelled. The introduction of LNG contracts in a gas portfolio brings into consideration two challenging issues. First, a company needs to determine a set of acceptable prices for the contracts. Second, on the basis of each contract's features, a company needs to determine an optimal portfolio. We address these two points being complex and intertwined.

Bjarne Foss, NTNU (with Vidar Gunnerud)

Real-time production optimization based on decomposition techniques

This presentation focusses on Dantzig-Wolfe decomposition for real-time optimization of oil and gas systems with a decentralized structure. The idea is to improve computational efficiency and transparency of a solution. The contribution lies in the application of the Dantzig-Wolfe method which allows us to efficiently decompose an optimization problem into parts. Moreover, we show how the algorithm can be parallelized for even higher efficiency. The nonlinear system is modeled by piecewise linear models with the added benefit that error bounds can be computed. In this context alternative parameterizations are discussed.

The properties of the method are studied by applying it to realistic models of petroleum fields. The examples lend themselves to a decomposition strategy due to the layout and structure of the wells and pipeline systems. The first model resembles the Troll west oil rim, a huge gas and oil field on the Norwegian Continental shelf. Decision variables are allocation of production between wells and routing of well streams. A second case also includes allocation of supply gas for gas lift. This is based on an on-going study of an offshore field outside Brazil.

Bruno Flach, IBM Research - Brazil (with Davi Valladao, Bianca Zadrozny)

An MIQP approach to the determination of analogous reservoirs

Oil companies are constantly faced with decision under uncertainty problems related to the analysis of potential investments in target reservoirs. Often, the amount of information on these prospects is relatively scarce and a common adopted strategy is having specialists determine analogous reservoirs - i.e., those for which plenty of data is available and are believed to be similar to the target - as a way to estimate unknown parameters and evaluate production forecasts. Machine learning algorithms, such as k-nearest-neighbors (KNN), may also be applied in this context but the quality of their results is intrinsically related with the definition of a distance metric that defines the similarity between the target reservoir and those stored in a database. To this end, our work focuses on the determination of an optimal distance function - in the sense of minimizing the error in the prediction of a given property or attribute obtained with the computed analogues - by formulating it as a mixed integer quadratic programming (MIQP) problem. Computational results on the application of different solution algorithms to a realistic large-scale problems will be discussed.

PDE-constrained opt. & multi-level/multi-grid meth.

Wed.1.MA 415

Optimization applications in industry III

Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics - Invited Session

Roland Herzog, TU Chemnitz (with Christian Meyer, Gerd Wachsmuth)

Optimal control of elastoplastic processes

Elastoplastic deformations are the basis of many industrial production techniques, and their optimization is of significant importance. We consider mainly the (idealized) case of infinitesimal strains as well as linear kinematic hardening. From a mathematical point of view, the forward system in the stress-based form is represented by a time-dependent variational inequality of mixed type. Its optimal control thus leads to an MPEC (mathematical program with equilibrium constraints) or an equivalent MPCC (mathematical program with complementarity constraints), both of which are challenging for general-purpose nonlinear optimization codes. In this presentation, we therefore address tailored algorithmic techniques for optimization problems involving elastoplastic deformation processes.

Anton Schiela, TU Berlin

An adaptive multilevel method for hyperthermia treatment planning

The aim of hyperthermia treatment as a cancer therapy is to damage deeply seated tumors by heat. This can be done regionally by a microwave applicator and gives rise to the following optimization problem: "Find antenna parameters, such that the damage caused to the tumor is maximized, while healthy tissue is spared". Mathematically, this is a PDE constrained optimization problem subject to the time-harmonic Maxwell equations, which govern the propagation of the microwaves, and the bio heat transfer equation, a semi-linear elliptic equation, which governs the heat distribution in the human body. Further, upper bounds on the temperature in the healthy tissue are imposed, which can be classified as pointwise state constraints.

In this talk we consider a function space oriented algorithm for the solution of this problem, which copes with the various difficulties. The state constraints are tackled by an interior point method, which employs an inexact Newton corrector in function space for the solution of the barrier subproblems. Herein, discretization errors are controlled by a-posteriori error estimation and adaptive grid refinement.

Michael Stingl, Friedrich-Alexander-University Erlangen-Nürnberg (with Fabian Schury, Fabian Wein)

Material optimization: From theory to practice

A two-scale method for the optimal design of graded materials is presented. On the macroscopic scale we use a variant of the so called free material optimization (FMO) approach, while on the microscopic scale the FMO results (a set of material tensors) are interpreted as periodic two-phase materials. In FMO an elastic body is optimized w.r.t. given forces and boundary conditions. Hereby the material properties are allowed to vary from point to point. In contrast to the standard model, continuity of the variation of the material properties is enforced. Moreover constraints on the symmetry of each tensor [e.g., orthotropy, cubic

symmetry) as well as special bounds on the stiffness of the material are added. The latter constraints are chosen compatible with the choice of the material on the microscopic level. Approximate solutions methods for this modified FMO problem are presented. In a discretized finite element setting the result of the macroscopic problem is a set of material tensors. Depending on the macroscopic constraints, these tensors are either directly interpreted as periodic microstructures or accessible through an inverse homogenization approach.

Robust optimization

Wed.1.MA 004

Applications of robust optimization III

Organizer/Chair Aurelie Thiele, Lehigh University - Invited Session

Elcin Cetinkaya, Lehigh University (with Aurelie Thiele)

Robust customized pricing

We study robust revenue management problems when companies request bids for services but their price-response function is not known precisely. The company bidding for these contracts only knows the previous bids it submitted to those businesses and whether they were accepted or not. We show how to derive tractable mathematical models for this problem and provide insights into the optimal solution. We also document the performance of the approach in numerical experiments

Ban Kawas, IBM Research - Zürich (with Marco Laumanns, Eleni Pratsini)

A robust optimization approach to enhancing reliability in production planning under non-compliance risks

We investigate a game-theoretic setup of a production planning problem under uncertainty in which a company is exposed to the risk of failing authoritative inspections due to non-compliance with enforced regulations. The outcome of an inspection is uncertain and is modeled as a Bernoulli distributed random variable whose parameter is a function of production decisions. We model non-compliance probabilities as uncertain parameters belonging to polyhedral uncertainty sets and maximize the worst-case expected profit over these sets. We derive convex tractable formulations, in the form of MIPs, that offer the flexibility of matching solutions to the level of conservatism of decision makers via two intuitive parameters. Varying these parameters when solving for the optimal product allocation provides different risk-return tradeoffs. We give strong empirical evidence that exhibits the superior performance of the devised model. We believe the robust approach holds much potential in enhancing reliability in production planning and other frameworks in which probabilities of random events depend on decision variables and in which parameter uncertainty is prevalent and difficult to handle.

Slawomir Pietrasz, Paris Dauphine - GDF Suez

Strategically robust investments on gas transmission networks

Looping regional gas transmission networks to increase their capacity involves considerable costs. Thus the corresponding investment decision occurs only after thoroughly weighing both the industrial and economic pros and cons. Wouldn't it be profitable to encompass those uncertainties from the top to deliver several equivalent investment alternatives that no decision maker would regret? Hence, we have focused on the evolving context of investment studies and identified uncertain technical, economic and strategic parameters who play a significant role in the out coming investment proposition. Analyzing what is at stake when it comes to robustness and flexibility has led us to introduce a mathematical risk measure which is interpretable in operational terms. We eventually offer a set of R&D approaches, that we hope, will contribute to shift present optimization models into future robust decision rules.

Sparse optimization & compressed sensing

Wed.1.H 1028

Algorithms for sparse optimization II

Organizer/Chair Kimon Fountoulakis, Edinburgh University - Invited Session

Kimon Fountoulakis, Edinburgh University (with Jacek Gondzio, Pavel Zhlobich)

Matrix-free interior point method for compressed sensing problems

We consider the class of ℓ_1 -regularization methods for sparse signal reconstruction from the field of Compressed Sensing. Such problems are very well conditioned and, indeed, can be solved easily by first-order methods, such as, GPSR, FPC_AS, SPGL1, NestA. Interior point methods rely on second-order information. They have many advantageous features and one clear drawback: in general, the solution of a Newton's system has computational complexity $\mathcal{O}(n^3)$. We remove this disadvantage by employing the matrix-free interior point method with suitable preconditioners which cleverly exploit special features of compressed sensing problems. Spectral analysis of the preconditioners is presented. Computational experience with large-scale

one-dimensional signals ($n = 2^{20}$) confirms that the new approach is efficient and compares favourably with other state-of-the-art solvers.

Xiangfeng Wang, Nanjing University (with Xiaoming Yuan)

Linearized alternating direction methods for Dantzig selector

The Dantzig selector was recently proposed to perform variable selection and model fitting in the linear regression model, and it can be solved numerically by the alternating direction method (ADM). In this paper, we show that the ADM for Dantzig selector can be speeded up significantly if one of its resulting subproblems at each iteration is linearized. The resulting linearized ADMs for Dantzig selector are shown to be globally convergent, and their efficiency is verified numerically by both simulation and real world data-sets.

Sergey Voronin, Princeton University

Iteratively reweighted least squares methods for structured sparse regularization

We describe two new algorithms useful for obtaining sparse regularized solutions to large inverse problems, based on the idea of reweighted least squares. We start from the standpoint of ℓ_1 minimization, and show that by replacing the non-smooth one norm $\|x\|_1 = \sum_{k=1}^N |x_k|$ with a reweighted two norm: $\sum_{k=1}^N w_k x_k^2$, with the weights being refined at each successive iteration, we can formulate two new algorithms with good numerical performance. We then discuss a generalization of both variants, useful in cases of structured sparsity, where different sets of coefficients demand different treatment. We discuss in particular, an example from a large inverse problem from Geotomography, where Wavelets are used to promote sparsity. We show that to build up a solution from a dictionary of different Wavelet bases and to have control over the different components of each Wavelet basis, the minimization of a more general functional: $\|Ax - b\|_2^2 + \sum_{k=1}^N \lambda_k |x_k|^{q_k}$ for $1 \leq q_k < 2$ is desirable. We show that our proposed schemes extend to this more general case.

Stochastic optimization

Wed.1.MA 141

Algorithms for stochastic optimization and approximation

Organizer/Chair Marc Steinbach, Leibniz Universität Hannover · Invited Session

Vaclav Kozmik, Charles University in Prague, Faculty of Mathematics and Physics (with David Morton)

Risk-averse stochastic dual dynamic programming

We formulate a risk-averse multistage stochastic program using CVaR as the risk measure. The underlying random process is assumed to be stage-wise independent, and the stochastic dual dynamic programming (SDDP) algorithm is applied. We discuss the poor performance of the standard upper bound estimator in the risk-averse setting and provide a modified procedure, which improves the upper bound estimator. Only mild conditions and modest additional computational effort are required to apply the new upper bound estimator. The procedure allows for significant improvement in the terms of applying desirable stopping rules for the SDDP algorithm in the risk-averse setting. We give a numerical example with a simple multistage asset allocation problem using a log-normal distribution for the asset returns.

Jens Hübner, Leibniz Universität Hannover (with Marc Steinbach)

Structure-exploiting parallel interior point method for multistage stochastic programs

Highly specialized and structure-exploiting solvers for the primal-dual system are essential to make interior point methods competitively applicable to multistage stochastic programs. In the underlying sequential direct approach, depth-first based recursions over the scenario tree and usage of hierarchical problem structures are the key ingredients to achieve memory-efficiency and reduce computational costs. Our parallel approach is based upon a node-distributing pre-process that applies a depth-first based splitting of the scenario tree. The node-related problem data are statically distributed among participating processes. Proper computation orders lead to little idle times and communication overhead. This way only few communication routines are required to parallelize the sequential algorithm for distributed memory systems without losing its benefiting features. We use generic implementation techniques to adapt conforming data distributions to the entire IPM data. Thus, distributed memory systems can be used to solve even huge problems exceeding shared-memory capacities. Theoretical concepts and numerical results will be presented.

Anthony Man-Cho So, The Chinese University of Hong Kong (with Sin-Shuen Cheung, Kun Cheng Wang)

Chance-constrained linear matrix inequalities with dependent perturbations: A safe tractable approximation approach

In the formulation of optimization models, the data defining the objective functions and/or constraints are often collected via estimation or sampling, and hence are only approximations of the nominal values.

One approach to incorporate data uncertainty in optimization models is through chance constrained programming. Although such an approach often leads to computationally difficult optimization problems, one of the successes is the development of so-called safe tractable approximations (STAs) of chance constrained programs. Currently, the STA approach mainly applies to problems where the data perturbations are independent. However, in some applications (e.g., portfolio optimization), the data perturbations are not independent, and so existing results cannot be applied. In this talk, we will demonstrate how tools from probability theory can be used to develop STAs of chance constrained programs with dependent data perturbations. An advantage of our approach is that the resulting STAs can be formulated as SDPs or even SOCPs, thus allowing them to be solved easily by off-the-shelf solvers. If time permits, we will also discuss some other applications of our approach.

Stochastic optimization

Wed.1.MA 144

Scheduling, control and moment problems

Chair Mariya Naumova, Rutgers University

Meggie von Haartman, inome (with Wolf Kohn)

Probabilistic realization resource scheduler with active learning

Many resource-scheduling applications require the construction of a model with predictive capabilities. The model is used to generate demand information as a function of historic data, resource constraints, sensory data, and other elements. Our research is directed towards the online construction and tuning of a semi-Markov model representing a stochastic process of demand. An optimization algorithm based on the optimal conditional probability measure associated with the stochastic process drives the construction. The conditional sequential residual entropy associated with the historic data gives the criterion: Maximization of residual entropy. The conditional probability measure associated with this model represents the demand at the current time, given the state information at the previous interval. The unique features of our approach are that a realization process in which the conditional probability is updated every time new information becomes available constructs the conditional probability. Another unique feature is that there is no a priori assumptions made about the associated probability space. This space is constructed and tuned as new information becomes available.

Regina Hildenbrandt, Ilmenau Technical University

Partitions-requirements-matrices as optimal Markov kernels of special stochastic dynamic distance optimal partitioning problems

The stochastic dynamic distance optimal partitioning problem (SDDP problem) is a complex Operations Research problem. The SDDP problem is based on a problem in industry, which contains an optimal conversion of machines.

Partitions of integers as states of these stochastic dynamic programming problems involves combinatorial aspects of SDDP problems. Under the assumption of identical "basic costs" (in other words of "unit distances") and independent and identically distributed requirements we will show (in many cases) by means of combinatorial ideas that decisions for feasible states with least square sums of their parts are optimal solutions. Corresponding Markov kernels are called partitions-Requirements-Matrices (PRMs).

Optimal decisions of such problems can be used as approximate solutions of corresponding SDDP problems, in which the basic costs differ only slightly from each other or as starting decisions if corresponding SDDP problems are solved by iterative methods, such as the Howard algorithm.

Mariya Naumova, Rutgers University (with Andras Prekopa)

Univariate discrete moment problem for new classes of objective function and its applications

We characterize the dual feasible bases, in connection with univariate discrete moment problem for classes of objective function not dealt with until now, e.g., step functions with finite number of values. Formulas for the optimum value and dual type algorithmic solutions will be presented. Applications will be mentioned to engineering design and finance.

Stochastic optimization

Wed.1.MA 376

Risk aversion in stochastic combinatorial optimization

Organizer/Chair Evdokia Nikolova, Texas A&M University · Invited Session

Jian Li, Tsinghua University (with Amol Deshpande)

Maximizing expected utility for stochastic combinatorial optimization problems

We study the stochastic versions of a broad class of combinatorial

problems where the weights of the elements in the input dataset are uncertain. The class of problems that we study includes shortest paths, minimum weight spanning trees, and minimum weight matchings over probabilistic graphs, and other combinatorial problems like knapsack. We observe that the expected value is inadequate in capturing different types of risk-averse or risk-prone behaviors, and instead we consider a more general objective which is to maximize the expected utility of the solution for some given utility function, rather than the expected weight (expected weight becomes a special case). We show that we can obtain a polynomial time approximation algorithm with additive error ϵ for any $\epsilon > 0$, and the maximum value of the utility function is bounded by a constant. Our result generalizes several prior results on stochastic shortest path, stochastic spanning tree, and stochastic knapsack. Our algorithm for utility maximization makes use of a technique to decompose a general utility function into exponential utility functions, which may be useful in other stochastic optimization problems.

Chaitanya Swamy, University of Waterloo

Risk-averse stochastic optimization: Probabilistically-constrained models and algorithms for black-box distributions

We consider various stochastic models that incorporate the notion of risk-averseness into the standard 2-stage recourse model, and develop techniques for solving the algorithmic problems arising in these models. A key notable and distinguishing feature of our work is that we obtain results in the black-box setting, where one is given only sampling access to the underlying distribution. One such model is what we call the risk-averse budget model, where we impose a probabilistic constraint that restricts the probability of the second-stage cost exceeding a given budget B to at most a given input threshold ρ . We devise an approximation scheme for solving the LP-relaxations of a variety of risk-averse budgeted problems. Complementing this, we give a rounding procedure that lets us use existing LP-based approximation algorithms for the 2-stage and/or deterministic counterpart of the problem to round the fractional solution. This yields approximation algorithms for various discrete optimization problems in our risk-averse models with black-box distributions. These are the first approximation results for problems involving probabilistic constraints with black-box distributions.

Abraham Othman, Carnegie Mellon University (with Tuomas Sandholm)

Inventory-based versus prior-based options trading agents

Options are a basic, widely-traded form of financial derivative that offer payouts based on the future price of an underlying asset. The finance literature gives us option-trading algorithms that take into consideration information about how prices move over time but do not explicitly involve the trades the agent made in the past. In contrast, the prediction market literature gives us automated market-making agents (like the popular LMSR) that are event-independent and price trades based only on the inventories the agent holds. We simulate the performance of five trading agents inspired by these literatures on a large database of recent historical option prices. We find that a combination of the two approaches produced the best results in our experiments: a trading agent that keeps track of previously-made trades combined with a good prior distribution on how prices move over time. The experimental success of this synthesized trader has implications for agent design in both financial and prediction markets.

Telecommunications & networks

Wed.1.H 3002

Network flows and network design

Organizer/Chair Bernard Fortz, Université Libre de Bruxelles · Invited Session

Tue Christensen, Aarhus University (with Martine Labbé)

Solving the piecewise linear network flow problem by branch-cut-and-price

In this paper we present an exact solution method for the network flow problem with piecewise linear costs. This problem is fundamental within supply chain management and extends the fixed-charge transportation problem in a straight-forward way. This kind of problem has numerous applications and allows modeling of different shipping modes such as packages, less-than-truckloads and truckloads, often found in the logistics and shipping industry. Additionally, it might be used to model price discounts, as often considered within procurement theory. We propose a Dantzig-Wolfe reformulation of the problem and extend this to an exact method by branching and the addition of valid inequalities. On a number of randomly generated test instances the

branch-cut-and-price method compares favorably to a standard mixed-integer programming solver with a significant reduction in runtime.

Bernard Fortz, Université Libre de Bruxelles (with Quentin Botton, Luis Gouveia)

The hop-constrained survivable network design problem with reliable edges

We study the hop-constrained survivable network design problem with reliable edges. Given a graph with non-negative edge weights and node pairs Q , the hop-constrained survivable network design problem consists of constructing a minimum weight set of edges so that the induced subgraph contains at least K edge-disjoint paths containing at most L edges between each pair in Q .

In this talk, we propose and study the hop-constrained survivable network design problem with so-called *reliable* edges where in addition, we consider a subset of edges that are not subject to failure. We study two variants (a static problem where the reliability of edges is given, and an upgrading problem where edges can be upgraded to the reliable status at a given cost). We adapt for the two variants an extended formulation proposed in [BFGP11] for the case without reliable edges. Due to the huge number of variables and constraints included in the extended formulations, we use Benders decomposition to accelerate the solving process. We develop an exact branch-and-cut algorithm and a fix-and-branch heuristic.

Edoardo Amaldi, Politecnico di Milano (with Antonio Capone, Stefano Coniglio, Luca Gianoli)

Network routing subject to max-min fair flow allocation

In the Max-min fairness (MMF) flow allocation principle not only the bandwidth of the commodity with the smallest allocation is maximized, but also in turn the second worst, the third worst and so on.

While in previous work the MMF principle has been used as routing objective, we consider it as a constraint, since it allows to well approximate TCP flow allocation when the routing paths are given.

We investigate the problem of, given a network and set of commodities, selecting a single path for each commodity so as to maximize a network utility function subject to MMF flow allocation. We compare some mathematical programming formulations, describe a column generation approach and report some computational results.

Variational analysis

Wed.1.H 2035

Nonsmooth variational inequalities: Theory and algorithms

Organizer/Chair Russell Luke, Universität Göttingen · Invited Session

Russell Luke, Universität Göttingen (with Heinz Bauschke, Hung Phan, Xianfu Wang)

Constraint qualifications for nonconvex feasibility problems

The current convergence theory for the method of alternating projections applied to nonconvex feasibility problems does not entirely cover the convex case as one might expect. We propose a restricted normal cone and the attendant sufficient set intersection qualifications that guarantee local linear convergence of nonconvex alternating projections. This generalization recovers all of the theory for consistent convex feasibility problems and yields new convergence results for nonconvex problems involving sparsity constraints.

Shoham Sabach, The Technion – Israel Institute of Technology (with Amire Beck)

A first order method for finding minimal norm-like solutions of convex optimization problems

We consider a general class of convex optimization problems in which one seeks to minimize a strongly convex function over a closed and convex set which is by itself an optimal set of another convex problem. We introduce a gradient-based method, called the minimal norm gradient method, for solving this class of problems, and establish the convergence of the sequence generated by the algorithm as well as a rate of convergence of the sequence of function values. A portfolio optimization example is given in order to illustrate our results.

Charitha Cherugondi, Universität Göttingen

A descent method for solving an equilibrium problem based on generalized D-gap function

The gap function approach for solving equilibrium problems has been investigated by many authors in the recent past. As in the case of variational inequalities, (EP) can be formulated as an unconstrained minimization problem through the D-gap function. We present a descent type algorithm for solving (EP) based on the generalized D-gap function. The convergence properties of the proposed algorithm under suitable assumptions has been discussed while supporting our approach with appropriate examples. We construct a global error bound for the equilibrium problem in terms of the generalized D-gap function. This error bound generalizes most of the existing error bounds for (EP) in the literature.

Variational analysis

Wed.1.H 2051

Quadratic and polynomial optimization

Organizer/Chair Jeya Jeyakumar, The University of New South Wales · Invited Session

Gwi Soo Kim, Pukyong National University, Busan, Republic of Korea (with Gue Myung Lee)

On ϵ -saddle point theorems for robust convex optimization problems

In this talk, we consider ϵ -approximate solutions for a convex optimization problem in the face of data uncertainty, which is called a robust convex optimization problem. Using robust optimization approach (worst-case approach), we define ϵ -saddle points for ϵ -approximate solutions of the robust convex optimization problem. We prove a sequential ϵ -saddle point theorem for an ϵ -approximate solution of a robust convex optimization problem which holds without any constraint qualification, and then we give an ϵ -saddle point theorem for an ϵ -approximate solution which holds under a weakened constraint qualification.

Jeya Jeyakumar, The University of New South Wales (with Guoyin Li)

Sum of squares representations and optimization over convex semialgebraic sets

We present sum of squares representations of positive or non-negative SOS-convex polynomials over non-compact convex sets without any qualifications. In the case of representations of positive polynomials, we allow representations to hold up to a positive constant, whereas for representations of non-negative polynomials, we permit them to hold asymptotically. Exploiting convexity of the systems and using hyperplane separations, we derive qualification-free representations in terms of sum of squares polynomials. Consequently, we show that for an SOS-convex optimization problem, its sum of squares relaxation problem is always exact. Stronger relaxation and duality results are given when a constraint qualification is present.

Guoyin Li, University of New South Wales (with Boris Mordukhovich)

Error bound for classes of polynomial systems and its applications: A variational analysis approach

Error bound is an important tool which provides an effective estimation of the distance from an arbitrary point to a set in terms of a computable "residual function". The study of error bound plays an important role in the convergence analysis of optimization algorithms and accurate identification of active constraints. In this talk, we are interested in error bound for classes of polynomial systems. Using variational analysis technique, we first show that global Lipschitz type error bound holds for a convex polynomial under Slater condition. When Slater condition is not satisfied, we establish a global Hölderian type error bound with an explicit estimate of the Hölderian exponent extending the known results for convex quadratic functions. Next, we extend these results to some classes of nonconvex system including piecewise convex polynomials and composite polynomial systems. Finally, as an application, we apply the error bound results to provide a quantitative convergence analysis of the classical proximal point method.

Approximation & online algorithms

Wed.2.H 3010

Approximation in routing and scheduling

Organizers/Chairs Nicole Megow, Technische Universität Berlin; Jose Correa, Universidad de Chile · Invited Session

Jose Soto, Universidad de Chile (with Jose Correa, Omar Larre)

The traveling salesman problem in cubic graphs

We prove that every 2-connected cubic graph on n vertices has a tour of length at most $(4/3 - \epsilon)n$, for a small, but positive ϵ . This in particular implies that the integrality gap of the Held and Karp LP relaxation for the TSP is strictly less than $4/3$ on this graph class.

Jose Verschae, Universidad de Chile (with Nicole Megow, Martin Skutella, Andreas Wiese)

The power of recourse for online MST and TSP

We consider online versions of MST and TSP problems with recourse. Assume that vertices of a complete metric graph appear one by one, and must be connected by a tree (respectively tour) of low cost. In the standard online setting, where decisions are irrevocable, the competitive factor of each algorithm is $\Omega(\log n)$. In our model, recourse is allowed by granting a limited number of edge rearrangements per iteration. More than 20 years ago, Imase and Waxman [1991] conjectured that constant-competitive solutions can be achieved with a constant (amortized) number of rearrangements. In this talk I will present an algorithm that solves this conjecture for MSTs in the amortized setting.

Unlike in offline TSP variants, the standard double-tree and short-cutting approach does not give constant guarantees in the online setting. However, a non-trivial *robust* shortcutting technique allows to con-

vert trees into tours at the loss of small factors, implying the conjecture of Imase and Waxman for tours.

For the non-amortized setting, we conjecture a structural property of optimal solutions that would imply a constant competitive ratio with one recourse action per iteration.

Claudio Telha, Universidad de Chile (with Jose Soto)

The jump number (maximum independent set) of two-directional orthogonal-ray graphs

We consider a special case of the *independent set of rectangles problem*. Given a family of white (W) and black (B) points in the plane, we construct the family \mathcal{R} of rectangles having bottom-left corner in W and top-right corner in B . The problem is to find the maximum cardinality of a collection of disjoint rectangles in \mathcal{R} .

We show that this problem can be efficiently solved using linear programming techniques. Inspired by this result, and by previous work of A. Frank, T. Jordan and L. Vegh on set-pairs, we describe a faster combinatorial algorithm that solves this problem in $\tilde{O}(|W| + |B|)^{2.5}$ time.

We also establish a connection between this special case of the independent set of rectangles problem and the problem of finding the *jump number* of a certain class of comparability graphs (known as two-directional orthogonal ray graphs). Using this connection, we can compute the jump number of convex graphs with n nodes in $O((n \log n)^{2.5})$ time, while previous algorithms for these instances ran in time at least $O(n^9)$.

Combinatorial optimization

Wed.2.H 3004

Extended formulations in discrete optimization III

Organizers/Chairs Volker Kaibel, Otto-von-Guericke Universität Magdeburg; Samuel Fiorini, Université libre de Bruxelles (ULB) · Invited Session

Hans Raj Tiwary, Université Libre de Bruxelles (with Samuel Fiorini, Thomas Rothvoss)

Extended formulations for polygon

The extension complexity of a polytope P is the smallest integer k such that P is the projection of a polytope Q with k facets. We discuss the extension complexity of n -gons in the plane. First, we give a new proof that the extension complexity of regular n -gons is $O(\log n)$. Next, we discuss lower bounds for the case when the polygon is not necessarily regular.

Michele Conforti, Dipartimento di Matematica - Università di Padova (with Laurence Wolsey, Giacomo Zambelli)

Extended formulations in mixed-integer programming

We study the convex hull of a mixed-integer set S by expressing each continuous variable as the average of k integral variables. This allows us to model S as a pure integer set in an extended space. The integrality of the additional variables allows us to strengthen the inequalities that describe S .

We concentrate on a mixed-integer set defined as follows: Given a bipartite graph $G = (U \cup V, E)$, a set $I \subseteq U \cup V$ and rational numbers b_{ij} , $ij \in E$, let

$$S^{(G,I)} = \{x \in \mathbb{R}^{U \cup V} \mid \sum_{i \in I} x_i = |I|, x_i \in \mathbb{Z} \text{ for } i \in I, x_{ij} \geq b_{ij} \text{ for } ij \in E\}.$$

We show that the set $S^{(G,I)}$ is equivalent to the "network dual" set introduced and studied by Conforti, Di Summa, Eisenbrand and Wolsey. Conforti et al. give an extended formulation for the polyhedron $\text{conv}(S^{(G,I)})$ and discuss cases in which the formulation is compact.

Our goal is to describe the polyhedron $\text{conv}(S^{(G,I)})$ in the space of the x variables and we give properties of the facet-defining inequalities. Our principal result is a characterization of the structure of facet-defining inequalities when the graph G is a tree.

Giacomo Zambelli, London School of Economics and Political Science (with Michele Conforti, Bert Gerards, Laurence Wolsey)

Mixed-integer bipartite vertex covers and mixing sets

The mixed-integer bipartite vertex-covering problem consists in optimally assigning weights to the nodes of a bipartite graph so that the sum of the weights on the endnodes of each edge is at least some prescribed edge-requirement, and that the weights on certain nodes are integer. Besides being the natural mixed-integer counterpart of the classical vertex-covering problem, this model arises as a relaxation of several lot-sizing problems. While no satisfactory polyhedral characterization is known, an extended formulation - albeit not polynomial in size - was given by Conforti, Di Summa, Eisenbrand and Wolsey. We give results on the projection of the extended formulation onto the original space, leading to full polyhedral characterizations for the case when the edge-requirements are half-integral and for certain classes of lot-sizing problems.

Combinatorial optimization

Wed.2.H 3005

Geometric combinatorial optimization

Chair Maurice Queyranne, Sauder School of Business at UBC

Maurice Queyranne, Sauder School of Business at UBC

Modeling convex subsets of points

A subset S of a given set P of points in a vector space is convex (relative to P) if every given point of P that is in the convex hull S is also in S . We are interested in modelling such discrete convexity restrictions which arise, usually in a low-dimensional space and subject to additional constraints, in many applications (e.g., mining, forestry, location, data mining, political districting, police quadrant design). This question is well understood in one dimension, where optimization can be solved in time that is linear (in the number $|P|$ of given points); a complete (but exponential-size) polyhedral description in the natural variables (that select the points in S), and a linear-time separation algorithm are known, as well as a linear-sized ideal extended formulation. On the other hand the optimization problem (to find a maximum weight convex subset of given points with weights of arbitrary signs) is NP-hard in dimensions three and higher, and inapproximable when the dimension is part of the input. In the two-dimensional plane, the optimization problem is solved in polynomial (cubic) time by dynamic programming [Bautista-Santiago et al., 2011] and, thanks to Carathéodory's

Eranda Dragoti-Cela, TU Graz (with Vladimir Deineko, Gerhard Woeginger)

On the x-and-y axes travelling salesman problem

We consider a special case of the Euclidean Travelling Salesman Problem (TSP) known as x-and-y-axes TSP. In this case all cities s are situated on the x -axis and on the y -axis of an orthogonal coordinate system for the Euclidean plane. This is a special case of the so-called Constrained TSP (CTSP) investigated by Rubinstein, Thomas and Wormald (2001), where the n cities lie on a given finite set G of smooth, compact curves in the plane, such that each curve has a finite length and the number of (self) intersections is finite. Moreover at each intersection the branches of the curve approach in different directions. Rubinstein et al. have shown that the CTSP is polynomially solvable, where the degree of the polynomial is large and depends on G and n . We show that for each circle around the origin the optimal tour of the x-and-y axes TSP contains at most eight edges leaving that circle. By considering one circle for each vertex we construct a dynamic programming scheme (DPS) which assembles the optimal tour by means of optimal sub-paths lying outside the circle and on one of the half-axes. A non-trivial analysis shows that this DPS leads to an $O(n^2)$ time algorithm.

Rafael Barbosa, Universidade Federal do Ceará (with Yoshiko Wakabayashi)

Algorithms for the restricted strip cover problem

Broadly speaking, sensor cover problems comprise problems of the following nature. Given a region to be covered by a set of sensors previously positioned, each one powered with a battery of limited duration, assign to each sensor an initial time, so as to cover the given region for as long as possible.

We investigate the one-dimensional version of the problem, called restricted strip cover problem, in which the region to be covered is an interval of the real line and the duration of the batteries is non-uniform.

We study both the preemptive and the non-preemptive case. In the first case, the sensors can be turned on and off more than once. For this case, we present a polynomial-time algorithm. For the non-preemptive case, known to be NP-hard, in 2009 Gibson and Varadarajan designed a polynomial-time algorithm which they proved to be a 5-approximation. We proved that this algorithm has approximation ratio 4, being this ratio tight. We present integer linear formulations for the non-preemptive case, and report on the computational results obtained with this approach, and some relaxations.

Combinatorial optimization

Wed.2.H 3008

Combinatorics and geometry of linear optimization IV

Organizer/Chair Friedrich Eisenbrand, TU Berlin · Invited Session

Bernd Gärtner, ETH Zürich (with Abel Camacho)

Abstract optimization problems revisited

Abstract Optimization Problems (AOP) generalize linear programs and have been invented with the goal of providing an abstract setting in which the subexponential randomized linear programming algorithms of Kalai and Matousek, Sharir and Welzl still work. Linear programming abstractions have also been considered recently by Eisenbrand et al., Kim, and others in the context of diameter bounds for polytopes. In

this talk, I want to discuss whether and how AOP relate to these new abstractions.

Marco Di Summa, Università degli Studi di Padova (with Nicolas Bonifas, Friedrich Eisenbrand, Nicolai Haehle, Martin Niemeier)

A new bound on the diameter of polyhedra

We derive a new upper bound on the diameter of the graph of a polyhedron $P = \{x \in \mathbb{R}^n : Ax \leq b\}$, where $A \in \mathbb{Z}^{m \times n}$. The bound is polynomial in n and the largest absolute value of a sub-determinant of A , denoted by Δ . More precisely, we show that the diameter of P is bounded by $O(\Delta^2 n^4 \log n \Delta)$. If P is bounded, then we show that the diameter of P is at most $O(\Delta^2 n^{3.5} \log n \Delta)$. For the special case in which A is a totally unimodular matrix, the bounds are $O(n^4 \log n)$ and $O(n^{3.5} \log n)$ respectively. This improves over the previous best bound of $O(m^{16} n^3 (\log mn)^3)$ due to Dyer and Frieze.

Edward Kim, Pohang University of Science and Technology

Subset partition graphs and an approach to the linear Hirsch conjecture

Combinatorial abstractions of the graphs of polyhedra are receiving renewed interest as an approach to the linear Hirsch and polynomial Hirsch conjectures, since Santos disproved the Hirsch conjecture, which was relevant in the theoretical worst-case running time of the simplex method for linear optimization. We will give a survey of several classical combinatorial abstractions for polyhedral graphs. Then we show how they fit into a more general framework, which leads to some variants of these earlier abstractions. This flexible framework is defined by combinatorial properties, with each collection of properties taken providing a variant for studying the diameters of polyhedral graphs. We present a variant which has superlinear diameter, which together with some combinatorial operations gives a concrete approach for disproving the linear Hirsch conjecture.

Combinatorial optimization

Wed.2.H 3012

Heuristics II

Chair Abderrezak Djadoun, ZAK Technology

Salim Bouamama, University of M'sila, Algeria (with Christian Blum, Abdallah Boukerram)

A population-based iterated greedy algorithm for the minimum weight vertex cover problem

Given an undirected, vertex-weighted graph, the goal of the minimum weight vertex cover problem is to find a subset of the vertices of the graph such that the subset is a vertex cover and the sum of the weights of its vertices is minimal. This problem is known to be NP-hard and no efficient algorithm is known to solve it to optimality. Therefore, most existing techniques are based on heuristics for providing approximate solutions in a reasonable computation time. Population-based search approaches have shown to be effective for solving a multitude of combinatorial optimization problems. Their advantage can be identified as their ability to find areas of the space containing high quality solutions. This paper proposes a simple and efficient population-based iterated greedy algorithm for tackling the minimum weight vertex cover problem. At each iteration, a population of solutions is established and refined using a fast randomized iterated greedy heuristic based on successive phases of destruction and reconstruction. An extensive experimental evaluation on a commonly used set of benchmark instances shows that our algorithm outperforms current state-of-the-art approaches.

Abderrezak Djadoun, ZAK Technology (with Ilhem Boussaid)

Random synchronized prospecting: A new metaheuristic for combinatorial optimization

In this contribution, we introduce Random Synchronized Prospecting (RSP), a new metaheuristic for solving NP-Hard combinatorial optimization problems. This metaheuristic is presented as a swarm intelligence (SI) technique inspired by the way two groups of individuals would collaborate and exchange information while prospecting the solution's search space. An example of the efficiency of this metaheuristic is presented by introducing the RSP-QAP algorithm, an adaptation of the RSP metaheuristic for the Quadratic Assignment Problem (QAP). Computational results of applying the RSP-QAP algorithm to over 60 instances from the QAPLIB are shown.

Combinatorial optimization

Wed.2.H 3013

Assignment problems

Chair Geir Dahl, University of Oslo

Geir Dahl, University of Oslo (with Richard Brualdi)

Generalized Birkhoff polytopes and majorization

The notion of majorization plays an important role in matrix theory and other mathematical areas, like combinatorics, probability and physics. The basic notion is an ordering of vectors according to their partial sums, but several extensions exist. The purpose of this talk is to give a (very) brief introduction to majorization theory and to present some recent work on a generalization of Birkhoff polytopes related to majorization. Recall that the Birkhoff polytope is the set of all doubly stochastic matrices of a fixed size (it also corresponds to the perfect matching polytope). Main results include a generalization of the Birkhoff - von Neumann theorem and a characterization of the faces of such generalized Birkhoff polytopes. This is joint work with Richard A. Brualdi (University of Wisconsin).

Olga Heismann, Zuse Institute Berlin (with Ralf Borndörfer, Achim Hildenbrandt)

The hypergraph assignment problem

The hypergraph assignment problem (HAP) generalizes the assignment problem on directed graphs to directed hypergraphs; it is motivated by railway scheduling applications. The HAP is NP-hard even for problems with small hyperarc sizes and hypergraphs with a special partitioned structure. We propose an integer programming approach to the HAP and investigate the associated polyhedron of feasible solutions. Further, we develop combinatorial procedures that provide heuristic approximation results.

Combinatorial optimization

Wed.2.H 3021

Graph partitioning and clustering

Organizer/Chair Renato Werneck, Microsoft Research Silicon Valley · Invited Session

Renato Werneck, Microsoft Research Silicon Valley (with Daniel Delling, Andrew Goldberg, Ilya Razenshteyn)

Exact combinatorial branch-and-bound for graph bisection

We present a novel exact algorithm for the minimum graph bisection problem, whose goal is to partition a graph into two equally-sized cells while minimizing the number of edges between them. Our algorithm is based on the branch-and-bound framework and, unlike most previous approaches, it is fully combinatorial. We present stronger lower bounds, improved branching rules, and a new decomposition technique that contracts entire regions of the graph without losing optimality guarantees. In practice, our algorithm works particularly well on instances with relatively small minimum bisections, solving large real-world graphs (with tens of thousands to millions of vertices) to optimality.

Christian Schulz, Karlsruhe Institute of Technologie (with Peter Sanders)

High quality graph partitioning

We present an overview over our graph partitioners KaFFPa (Karlsruhe Fast Flow Partitioner) and KaFFPaE (KaFFPa Evolutionary). KaFFPa is a multilevel graph partitioning algorithm which on the one hand uses novel local improvement algorithms based on max-flow and min-cut computations and more localized FM searches and on the other hand uses more sophisticated global search strategies transferred from multi-grid linear solvers. KaFFPaE is a distributed evolutionary algorithm to solve the Graph Partitioning Problem. KaFFPaE uses KaFFPa which provides new effective crossover and mutation operators. By combining these with a scalable communication protocol we obtain a system that is able to improve the best known partitioning results for many inputs.

Henning Meyerhenke, Karlsruhe Institute of Technologie (with David Bader, Jason Riedy)

Current trends in graph clustering

Graph clustering has become very popular in recent years and is also known as community detection in networks. Generally speaking, graph clustering aims at the identification of vertex subsets with many internal and few external edges. The problem of finding clusters based on the objective function modularity was one category in the recently finished 10th DIMACS Implementation Challenge. We review successful techniques determined by the outcome of the challenge and describe our work on parallelization strategies.

Complementarity & variational inequalities

Wed.2.MA 313

Advances in the theory of complementarity and related problems II

Chair Joachim Gwinner, Universität der Bundeswehr München

Maria Lignola, University of Naples Federico II (with Jacqueline Morgan)

Mathematical programs with quasi-variational inequality constraints

We illustrate how to approximate the following values for mathematical programs with quasi-variational inequality constraints

$$\omega = \inf_{x \in X} \sup_{u \in Q(x)} f(x, u) \quad \text{and} \quad \varphi = \inf_{x \in X} \inf_{u \in Q(x)} f(x, u),$$

where

$$Q(x) = \{u \in S(x, u) : \langle A(x, u), u - w \rangle \leq 0 \quad \forall w \in S(x, u)\},$$

via the values of appropriate regularized programs under or without perturbations.

In particular, we consider the case where the constraint set X and the constraint set-valued mapping S are defined by inequalities

$$X = \{x : g_i(x) \leq 0, i = 1, \dots, m\}$$

$$S(x, u) = \{w : h_j(x, u, w) \leq 0, j = 1, \dots, n\}.$$

Using suitable regularizations for quasi-variational inequalities, we determine classes of functions f, g_i, h_j allowing to obtain one-sided (from above and below) approximation of φ and ω , and classes of functions providing a global approximation.

Fabio Raciti, University of Catania (with Francesca Faraci)

On generalized Nash equilibrium problems: The Lagrange multipliers approach

We study a class of generalized Nash equilibrium problems and characterize the solutions which have the property that all players share the same Lagrange multipliers. Nash equilibria of this kind were introduced by Rosen in 1965, in finite dimensional spaces. In order to obtain the same property in infinite dimension we use very recent developments of a new duality theory. In view of its usefulness in the study of time-dependent or stochastic equilibrium problems an application in Lebesgue spaces is given.

Joachim Gwinner, Universität der Bundeswehr München

On linear differential variational inequalities

Recently Pang and Stewart introduced and investigated a new class of differential variational inequalities in finite dimensions as a new modeling paradigm of variational analysis. This new subclass of general differential inclusions unifies ordinary differential equations with possibly discontinuous right-hand sides, differential algebraic systems with constraints, dynamic complementarity systems, and evolutionary variational systems. In this contribution we lift this class of nonsmooth dynamical systems to the level of a Hilbert space, but in contrast to recent work of the author we focus to linear input/output systems. This covers in particular linear complementarity systems studied by Heemels, Schumacher and Weiland. Firstly, we provide an existence result based on maximal monotone operator theory. Secondly we present a novel upper set convergence result with respect to perturbations in the data, including perturbations of the associated linear maps and the constraint set.

Conic programming

Wed.2.H 2036

Semidefinite programming and geometric representations of graphs

Organizers/Chairs Monique Laurent, CWI, Amsterdam and U Tilburg; Christoph Helmberg, TU Chemnitz · Invited Session

Susanna Reiss, Chemnitz University of Technologie (with Frank Göring, Christoph Helmberg)

Optimizing extremal eigenvalues of the weighted Laplacian of a graph

We study connections between the eigenspaces of the graph's Laplacian and graph properties. For this purpose, we analyze optimal solutions of

$$\min_w \{\lambda_{\max}(L_w(G)) - \lambda_2(L_w(G))\},$$

by semidefinite programming techniques, i.e., we optimize nonnegative edge weights w of a graph, that sum up to one, so as to minimize the difference of the maximum and the second smallest eigenvalue of the corresponding weighted Laplacian $L_w(G)$. The dual program may be interpreted as a graph realization problem in Euclidean space, that reflects the optimized eigenspaces. We present connections between structural properties of the graph (especially its separator structure) and geometrical properties of optimal graph realizations, thereby shedding light on

relations between the graph's properties and its eigenvectors. Furthermore we are able to prove the existence of optimal graph realizations whose dimensions are bounded by the tree-width of the graph plus one.

Marcel de Carli Silva, University of Waterloo (with Levent Tunçel)

Optimization problems over unit-distance representations of graphs

We start with a result of Lovász relating the theta number of a graph to its smallest radius hypersphere embedding where each edge has unit length. We use this identity and its generalizations to establish close relationships among many related graph parameters. We then study the more general problem of finding the smallest radius of an ellipsoid of a given shape that contains an embedding of a given graph where each edge has unit length.

This talk is based on joint work with Levent Tunçel.

Antonios Varvitsiotis, Centrum Wiskunde & Informatica (with Marianna Eisenberg-Nagy, Monique Laurent)

Two new graph parameters related to semidefinite programming with a rank constraint

We consider geometric representations of edge weighted graphs obtained by assigning unit vectors to the nodes, such that the weight of each edge is equal to the inner product of the vectors assigned to its endpoints. We introduce two new graph parameters related to the minimum dimension where such representations exist. Their study is motivated by their relevance to bounded rank positive semidefinite matrix completions and to the graphical Grothendieck problem with a rank constraint.

In this talk we analyze combinatorial and geometric properties of these parameters. In particular, we provide forbidden minor characterizations as well as structural and complexity results. Additionally, we discuss how our results imply some known characterizations of parameters related to Euclidean graph realizations and Colin de Verdière-type graph invariants.

Conic programming

Wed.2.H 2038

Conic and convex programming in statistics and signal processing III

Organizer/Chair Venkat Chandrasekaran, Caltech · Invited Session

Deanna Needell, Claremont McKenna College

Randomized projection algorithms for overdetermined linear systems

In this talk we discuss variations to projection onto convex sets (POCS) type methods for overdetermined linear systems. POCS methods have found many applications ranging from computer tomography to digital signal and image processing. The Kaczmarz method is one of the most popular solvers for overdetermined systems of linear equations due to its speed and simplicity. Here we introduce and analyze extensions of this method which provide exponential convergence to the solution in expectation which in some settings significantly improves upon the convergence rate of the standard method.

Stephen Wright, University of Wisconsin-Madison (with Caroline Uhler)

Packing ellipsoids (and chromosomes)

Problems of packing shapes with maximal density, possibly into a container of restricted size, are classical in mathematics. We describe here the problem of packing ellipsoids of given (and varying) dimensions into a finite container of given size, allowing overlap between adjacent ellipsoids but requiring some measure of total overlap to be minimized. A trust-region bilevel optimization algorithm is described for finding local solutions of this problem – both the general case and the more elementary special case in which the ellipsoids are in fact spheres. Tools from conic optimization, especially semidefinite programming and duality, are key to the algorithm. Theoretical and computational results will be summarized. Our work is motivated by a problem in structural biology – chromosome arrangement in cell nuclei – for which results are described.

James Saunderson, Massachusetts Institute of Technology (with Pablo Parrilo)

Polynomial-sized semidefinite representations of derivative relaxations of spectrahedral cones

The hyperbolicity cones associated with the elementary symmetric polynomials provide an intriguing family of non-polyhedral relaxations of the non-negative orthant that preserve its low-dimensional faces and successively discard higher dimensional structure. A similar construction gives a family of outer approximations for any spectrahedral cone (i.e. slice of the psd cone), and more generally for any hyperbolicity cone. We show, by a simple and explicit construction, that these derivative relaxations of spectrahedral cones have polynomial-sized representations as projections of slices of the psd cone. This, for example, allows us to solve the associated linear cone program using semidefinite programming, and allows us to give corresponding explicit semidefinite repre-

sentations for the (thus far poorly understood) duals of the derivative relaxations of spectrahedral cones.

Constraint programming

Wed.2.H 3003A

Constraint solvers and implementations

Organizer/Chair Narendra Jussien, École des Mines de Nantes · Invited Session

Christian Schulte, KTH Royal Institute of Technology

Gecode: An open constraint solving library

Gecode is a widely used toolkit for developing constraint-based systems and applications. Gecode provides a constraint solver with state-of-the-art performance while being modular and extensible. Gecode is: open (documented interfaces support tasks from modeling to implementing new variables, constraints, search engines, ...), free (MIT license), portable (standard C++), accessible (extensive tutorial and reference documentation, efficient (excellent performance, it has won the 2008–2011 MiniZinc challenges in all categories), and parallel (using today's multi-core hardware).

The talk provides an overview of what Gecode is, what one can do with it, and what are the key ideas behind it. The talk will in particular focus on Gecode being radically open and accessible as a consequence of its principled design and the commitment to publish and document Gecode's many contributions to today's state-of-the-art in the design and implementation of constraint solvers.

Bruno De Backer, Google

Constraint programming and optimization at Google

This talk will present examples of the use of constraint programming and combinatorial optimization at Google. I will also mention the tools that are being developed and disseminated as open-source software.

Charles Prud'homme, Ecole de Mines de Nantes (with Rémi Douence, Narendra Jussien, Xavier Lorca)

A DSL for programming propagation engine

Constraint propagation is at the heart of constraint solvers. Classically, a variation of the AC3 algorithm (including AC5, AC6, etc.) is implemented. Two main variations co-exist: variable-oriented propagation engines and constraint-oriented propagation engines. Those two approaches ensure the same consistency level (AC) but their efficiency (time computation) can be quite different according to the problem. There is no best approach in general. In this talk, we would like to go a step forward enabling the user to describe her own revision ordering/propagation engine. We first introduce an architecture that allows to naturally and efficiently compose state-of-the-art revision orderings. Next, we show that recent features like propagator groups can be extended in order to accurately configure the revision ordering within the propagation loop. Finally, we propose a domain specific language to allow users design their own propagation engine. We validate our proposal focusing on possible adaptations of a constraint solver to a wide range of problems.

Derivative-free & simulation-based opt.

Wed.2.H 3503

Derivative-free applications and parallelization

Chairs Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory

Aurea Martínez, Universidad de Vigo (with Lino Alvarez-Vazquez, Carmen Rodríguez, Miguel Vazquez-Mendez, Miguel Vilar)

Design of river fishways: A derivative-free optimization perspective

The main objective of this talk consists of presenting an application of mathematical simulation and optimal control theory to an ecological engineering problem related to preserve and enhance natural stocks of fish which migrate between salt and fresh water. River fishways are hydraulic structures that enable fish to overcome stream obstructions (as dams in hydroelectric power plants). Particularly, we are interested in improving the optimal shape design of these fishways. The problem can be formulated within the framework of the optimal control of partial differential equations, approximated by a discrete optimization problem, and solved by using a gradient-free method (the Nelder-Mead algorithm). Finally, numerical results are shown for a standard real-world situation, and compared to the results recently achieved by the authors in a joint work with J. Judice via a gradient-type method (a spectral projected gradient algorithm).

A. Ismael Vaz, University of Minho (with Paulo Antunes, Rui Guimarães, Júlio Viana)

Vibration-based structural health monitoring based on a derivative-free global optimization approach

Structural health monitoring (SHM) of critical parts is assuming a relevant role in several engineering fields such as civil, aeronautical and

aerospatial. Several SHM techniques are able to determine the presence of structural damage. However, the location and damage severity estimation are more difficult to determine.

In this talk, a new SHM approach based on optimization techniques is shown. This method is capable of, simultaneously, locate, determine the type of damage and output its severity. The considered objective function measures how well structural damage simulated data (obtained by using finite element models) compares with the observed data from the (un)damaged part in service. For 2D parts, four damage spatial variables and three material properties variables are considered. Due to the simulation process involved, objective function derivatives are unavailable and the objective function evaluations are costly. Numerical results also show that, in order to properly determine the damage location and severity, the optimization problem has to be solved globally. We present some successful numerical results using the PSwarm solver.

Per-Magnus Olsson, Linköping University (with Holmberg Kaj, Olsson Per-Magnus)

Parallelization of algorithms for derivate-free optimization

In this talk we present parallelization and extensions of algorithms for derivative-free optimization. In each iteration, we run several instances of an optimization algorithm with different trust region parameters, and each instance generates a point for evaluation. All points are kept in a common priority queue and the most promising points are evaluated in parallel when computers are available. We use models from several instances to prioritize the points and in case new information becomes available, we allow dynamic prioritization of points to ensure that computational resources are used efficiently. A database is used to avoid reevaluation of points. Together, these extensions make it easier to find several local optima and rank them against each other, which is very useful when performing robust optimization. Empirical testing reveals considerable decreases in the number of function evaluations as well as in the time required to solve problems.

Finance & economics

Wed.2.H 3027

Optimization methodologies in computational finance

Organizer/Chair Wei Xu, Tongji University · Invited Session

Cristinca Fulga, Institute of Mathematical Statistics and Applied Mathematics of Romanian Academy

Higher moments and conditional value at risk optimization

In order to control their exposure to risk, financial institutions are in charge of estimating risks caused by changes in asset prices and exchange and/or interest rates. Due to present regulations, the risk management of portfolios is intimately related to value at risk. For VaR calculation, there is the straightforward formula that can be used under the assumption that the log-returns of the portfolio are normally distributed and according to which VaR can be expressed in terms of mean and variance. But empirical evidence shows that, generally, financial returns are not normally distributed. In this paper we find the expression of VaR (and conditional value at risk) in terms of higher moments of the input loss distribution and compare the importance of different moments in VaR and CVaR. Using the maximum entropy principle, we find the best fit for the empirical probability distribution function in terms of its empirical moments. Their weights indicate which of them should be used in the Cornish-Fisher expansion. The VaR and CVaR approximation formulas are used to reduce the computational effort for large portfolio optimization problems.

Wei Xu, Tongji University (with Zhiwu Hong)

A new sampling strategy willow tree method with application to path-dependent option pricing

Willow tree algorithm, first developed by Curran in 1998, provides an efficient option pricing procedure. However, it leads to a big bias using Curran's sampling strategy when the number of points at each time step is not large. Thus, in this paper, we propose a new sampling strategy with solving a small nonlinear least square problem. Compared with Curran's sampling strategy, the new strategy gives a much better estimation of the standard normal distribution with small amount of sampling spatial points. Then, we apply the willow tree algorithm with the new sampling strategy to price path-dependent options such as American, Asian and American moving-average options. The numerical results illustrate that the willow tree algorithm is much more efficient than the least square Monte Carlo method and binomial tree method.

Asaf Shupo, MBNA Canada TD Bank Group (with Dragos Calitoiu, Hasan Mytkoliti)

Optimal promotion rate in a cash campaign

Taking care of customers and serving them better by building optimal strategies meeting their financial needs are the most important challenges to maintain existing customers and to remain profitable. In the scenario when a company lends money to its customers, the process of assigning to each offer the optimum interest rate becomes a complex

task, considering many other offers from competitors and considering that, in many cases, the goal of lending is not only the profit while reducing risk but also satisfying real needs of customers.

This current research presents the results of implementing our previous reported network optimization approach that uses customer level scores produced by a suite of cash models. This implementation is a real-life application which helps building optimal promotion campaigns by offering the optimal interest rates to each customer. In summary, from the mathematical perspective, this application provides an integer optimal solution which optimizes a goal function subject to some budgeted and business constraints. The improvement of using this optimization process vs. the classical approach was evident in all campaigns investigated in this research.

Game theory

Wed.2.MA 005

Polynomial-time algorithms for mechanism design

Organizer/Chair Berthold Vöcking, RWTH Aachen University · Invited Session

Piotr Krysta, University of Liverpool (with Dimitris Fotakis, Carmine Ventre)

Combinatorial auctions with verification

We study mechanism design for social welfare maximization in combinatorial auctions with general bidders. It is a major open problem in this setting to design a deterministic truthful auction which would provide the best possible approximation guarantee in polynomial time, even if bidders are double-minded (i.e., they assign positive value to only two sets in their demand collection of sets). On the other hand, there are known such randomized truthful auctions in this setting. We introduce a general model of verification (i.e., some kind of overbidding can be detected) and we design in this model the first deterministic truthful auctions which indeed provide essentially the best possible approximation guarantees achievable by any polynomial-time algorithm. This shows that deterministic truthful auctions have the same power as randomized ones if the bidders withdraw from unrealistic lies.

Gergely Csapo, Maastricht University (with Rudolf Müller)

The private provision of a public good: Digging for gold

We study the problem of finding the profit-maximizing mechanism for the provision of a single, non-excludable public good. This problem has been well studied for the case when the valuations of the agents are independently distributed, but the literature is silent about the general case. We focus on general joint distributions, characterizing the deterministic mechanism implementable in dominant-strategies that yields the maximum revenue for the monopolistic provider of the public good. We investigate the problem from an automated mechanism design perspective and show that finding the optimal mechanism can be solved in time polynomial in the number of types by reducing it to a maximal closure problem with respect to sum of conditional virtual values. We also conclude that in case of independent type distributions the optimal mechanism is the same as under Bayesian implementation and interim individual rationality.

Angelina Vidali, University of Vienna (with George Christodoulou, Amos Fiat, Anna Karlin, Elias Koutsoupias)

Scheduling, auctions and truthfulness

I will give an introduction and present some of my recent results in one of the most fundamental problems in algorithmic game theory and mechanism design: the problem of scheduling unrelated machines to minimize the makespan. I will emphasize the connection between this problem and the problem of designing truthful auctions for selling multiple items.

Finally I will present a geometrical characterization of truthfulness and also some very recent work on strongly truthful mechanisms.

We assume that the machines behave like selfish players: they have to get paid in order to process the tasks, and would lie about their processing times if they could increase their utility in this way. The problem was proposed thirteen years ago in the seminal paper of Nisan and Ronen, where it was shown that the approximation ratio of mechanisms is between 2 and n . I improve this to $1 + \sqrt{2}$ for three or more machines and to $1 + \phi$ for many machines. I also characterize the class of truthful mechanisms for the case of two players (regardless of approximation ratio) and show how the result can be used as a black box to obtain characterizations for other domains.

Game theory

Wed.2.MA 043

Analysis of auction mechanisms

Organizer/Chair Vangelis Markakis, Athens University of Economics and Business · Invited Session

Renato Paes Leme, Cornell University (with Gagan Goel, Vahab Mirrokni)

Polyhedral clinching auctions and the AdWords polytope

A central issue in applying auction theory in practice is the problem of dealing with budget-constrained agents. A desirable goal in practice is to design incentive compatible, individually rational, and Pareto optimal auctions while respecting the budget constraints. Achieving this goal is particularly challenging in the presence of nontrivial combinatorial constraints over the set of feasible allocations. Toward this goal and motivated by AdWords auctions, we present an auction for polymatroidal environments satisfying the above properties. Our auction employs a novel clinching technique with a clean geometric description and only needs an oracle access to the submodular function defining the polymatroid. As a result, this auction not only simplifies and generalizes all previous results, it applies to several new applications including AdWords Auctions, bandwidth markets, and video on demand. In particular, our characterization of the AdWords auction as polymatroidal constraints might be of independent interest. This allows us to design the first mechanism for Ad Auctions taking into account simultaneously budgets, multiple keywords and multiple slots.

Ioannis Caragiannis, University of Patras & CTI (with Christos Kaklamanis, Panagiotis Kanellopoulos, Maria Kyropoulou, Brendan Lucier, Renato Paes Leme, and Eva Tardos)

Welfare and revenue guarantees in sponsored search auctions

In sponsored search auctions, advertisers compete for a number of available advertisement slots of different quality. The auctioneer decides the allocation of advertisers to slots using bids provided by them. Since the advertisers may act strategically and submit their bids in order to maximize their individual objectives, such an auction naturally defines a strategic game among the advertisers. We consider generalized second price and generalized first price auctions in settings where the advertisers have incomplete information and present bounds on the social welfare over Bayes-Nash equilibria compared to the optimal social welfare. We also consider auctions that use a single reserve price and provide similar bounds on the revenue. Even though the above auctions are inferior to variations of the well-known VCG auction mechanism both in terms of welfare and revenue, our results provide explanations for their adoption by the sponsored search industry.

Vasilis Syrgkanis, Cornell University (with Renato Paes Leme, Eva Tardos)

Efficiency in sequential auctions

In many settings agents participate in multiple different auctions that are not necessarily implemented simultaneously. Future opportunities affect strategic considerations of the players in each auction, introducing externalities. Motivated by this consideration, we study a setting of a market of buyers and sellers, where each seller holds one item, bidders have combinatorial valuations and sellers hold item auctions sequentially. We examine both the complete and incomplete information version of the setting.

For the complete information setting we prove that if sellers hold sequential first price auctions then for unit-demand bidders (matching market) every subgame perfect equilibrium achieves at least half of the optimal social welfare, while for submodular bidders or when second price auctions are used, the social welfare can be arbitrarily worse than the optimal. For the incomplete information setting we prove that for the case of unit-demand bidders any Bayesian equilibrium achieves at least $\frac{1}{3}$ of the optimal welfare.

Global optimization

Wed.2.H 2053

Global optimization methods and applications

Organizer/Chair Sergiy Butenko, Texas A&M University · Invited Session

Panos Pardalos, University of Florida, USA (& HSE Moscow, Russia) (with Pando Georgiev)

Global optimality conditions in non-convex optimization

In this talk we are going to present recent results regarding global optimality conditions for general non-convex optimization problems. First we are going to discuss complexity issues regarding the existence of points satisfying optimality conditions and the connection to complementarity problems. In addition, we are going to discuss surprising connections between optimality conditions and continuous formulations of discrete optimization problems. In the second part of the talk we are go-

ing to discuss our recent result regarding optimality conditions of locally Lipschitz functions.

Erick Moreno-Centeno, Texas A&M University (with Richard Karp)

Solving combinatorial optimization problems as implicit hitting set problems

The hitting set problem is: given a set U and a family S of subsets of U , find a minimum-cardinality set that intersects each set in S . In the implicit hitting set problem, S is given via an oracle which verifies that a given set is a hitting set or returns a not-intersected set from S . Many NP-hard problems can be solved as implicit hitting set problems. We solve the implicit hitting set problem by combining efficient heuristics and exact methods. We present computational results for the minimum-feedback-vertex-set and the multiple-genome alignment problems.

Austin Buchanan, Texas A&M University (with Sergiy Butenko, Anurag Verma)

Maximum clique problem on very large scale sparse networks

We define a new clique relaxation called a k -community, and explore scale reduction techniques based on it to obtain the maximum clique on very large-scale real life networks. Analytically, the technique has been shown to be very effective on power-law random graphs. Experimental results on real life graph instances (collaboration networks, P2P networks, social networks, etc.) show our procedure to be much more effective than a regular k -core peeling approach.

Implementations & software

Wed.2.H 0110

Exact MIP/LP solvers

Organizer/Chair Daniel Steffy, Oakland University · Invited Session

Sebastian Hoffmann, Johannes Gutenberg-Universität Mainz (with Ernst Althaus, Bernd Becker, Daniel Dumitriu, Stefan Kupferschmid)

Integration of an LP solver into interval constraint propagation

In this talk we describe the integration of a linear program (LP) solver into iSAT, a Satisfiability Modulo Theories (SMT) solver that can solve Boolean combinations of linear and nonlinear constraints. iSAT is a tight integration of the well-known DPLL algorithm and interval constraint propagation (ICP) allowing it to reason about linear and nonlinear constraints. As interval arithmetic is known to be less efficient on solving linear programs, we will demonstrate how the integration of an LP solver can improve the overall solving performance of iSAT.

Kati Wolter, Zuse Institute Berlin (ZIB) (with William Cook, Thorsten Koch, Daniel Steffy)

An exact rational mixed-integer programming solver

We present an exact rational solver for mixed-integer programming that avoids the numerical inaccuracies inherent in the floating-point computations used by existing software. This allows the solver to be used for establishing theoretical results and in applications where correct solutions are critical due to legal and financial consequences. Our solver is a hybrid symbolic/numeric implementation of LP-based branch-and-bound, using numerically-safe methods for all binding computations in the search tree. Computing provably accurate solutions by dynamically choosing the fastest of several safe dual bounding methods, our exact solver is only moderately slower than an inexact floating-point branch-and-bound solver. The software is incorporated into the SCIP optimization framework. Computational results are presented for a suite of test instances taken from the MIPLIB and Mittelmann libraries and for a collection of numerically difficult instances.

Ojas Parekh, Sandia National Labs (with Robert Carr, Harvey Greenberg, Cynthia Phillips)

Computing certificates for integer programs

A certificate for an integer programming (IP) computation is information that allows an independent program to check that the output is correct, preferably far faster than the time required to compute the solution. The canonical example is the primal/dual certificate for a linear program (LP). Although solving an LP can take a large amount of time, checking a certificate requires two matrix vector multiplications and two dot products. A brute force certificate for an integer program branch-and-bound computation must prove that each branching operation, added cut, and fathoming operation is correct. We will discuss what this entails in the context of PICO, our massively parallel integer programming solver. We give certificates for some general cut classes and discuss ways to prove the correctness of a general cut, which is equivalent to another integer program. These integer programs appear to be significantly easier than the original IP. Intuitively, they are equivalent to proving integer infeasibility for the polytopes "cut off". We will discuss numerical and other implementation issues and give computational results for moderate-sized IPs.

Implementations & software

Wed.2.H 1058

Software for PDE-constrained optimization

Organizer/Chair Denis Ridzal, Sandia National Labs · Invited Session

Joseph Young, Sandia National Laboratories (with Denis Ridzal)

Software abstractions for matrix-free PDE optimization with cone constraints

In this presentation, we describe algorithms and software abstractions for a matrix-free code for PDE constrained optimization problems that contain both equality as well as cone constraints. The key to our discussion lies in the development of simple algebraic abstractions that allow us to build an efficient code and how these abstractions change between the different kinds of constraints. In addition to the theoretical and practical utility of this approach, we integrate these ideas into a new matrix-free code called ROL and present numerical examples.

Andreas Potschka, Heidelberg University (with Hans-Georg Bock)

MUSCOP: A multiple shooting code for time-periodic parabolic PDE constrained optimization

Time-periodic parabolic PDE constraints arise in important applications in chemical engineering, e.g., in periodic adsorption processes. We present the software package MUSCOP which was designed to solve such optimization problems. The GNU Octave/C++ code is based on a hybrid programming principle to allow for rapid development without sacrificing computational speed. Algorithmically, MUSCOP is based on the Method of Lines, Direct Multiple Shooting, inexact Sequential Quadratic Programming, and indefinite two-grid Newton-Picard preconditioning. For the generation of first and second order derivatives, MUSCOP relies heavily on Internal Numerical Differentiation and Algorithmical Differentiation within the adaptive C++ integrator suite SolvIND and the package ADOL-C. We explain the parallelization and mathematical exploitation of structures arising from the Direct Multiple Shooting and the two-grid approach. Grid-independent convergence can be observed in the numerical experiments and even be proved for a typical model problem. We conclude the talk with numerical results for problems ranging from academic models to a real world SMB process.

Drosos Kourounis, USI

Gradient-based optimization using adjoint methods for optimization of compositional flow in porous media

Adjoint-based gradients form an important ingredient of fast optimization algorithms for computer-assisted history matching and life-cycle production optimization. Large-scale applications of adjoint-based reservoir optimization reported so far concern relatively simple physics, in particular two-phase (oil-water) or three-phase (oil-gas-water) applications. In contrast, compositional simulation has the added complexity of frequent flash calculations and high compressibilities which potentially complicate both the adjoint computation and gradient-based optimization, especially in the presence of complex constraints. These aspects are investigated using a new adjoint implementation in a research reservoir simulator designed on top of an automatic differentiation framework coupled to a standard large-scale nonlinear optimization package. Optimization of strongly compressible flow with constraints on well rates or pressures leads to slow convergence and potentially poor performance. We present a pragmatic but effective strategy to overcome this issue.

Integer & mixed-integer programming

Wed.2.H 2013

Scheduling II

Chair Mahmut Gokce, Izmir University of Economics

Karin Thörnblad, Chalmers University of Technology (with Torgny Almgren, Michael Patriksson, Ann-Brith Strömberg)

A time-indexed formulation of a flexible job shop problem including preventive maintenance and availability of fixtures

We study a real-world problem arising in the scheduling of a production cell for aero engine components. This problem can be described as a flexible job shop problem with ten resources, where some of the jobs are subject to precedence constraints with time lags. The objective is the minimization of a weighted sum of the completion times and the total tardiness. The scheduling of the cell must be fast and produce reliable and robust schedules, since the conditions are unceasingly changing with new jobs continuously arriving at the queue. During the production a number of preventive maintenance activities need to be regularly carried out in specific resources of the cell. Further, in the processing of a job, the corresponding component needs to be mounted into a certain fixture; only a limited number of fixtures are available and each fixture is compatible only with a subset of the jobs. We present a time-

indexed mathematical model of this flexible job shop problem including the scheduling of the preventive maintenance activities and subject to the fixture availability. Computational results for real instances collected during the spring of 2012 are also presented.

Adam Wojciechowski, Chalmers University of Technology (with Emil Gustafsson, Magnus Önnheim, Michael Patriksson, Ann-Brith Strömberg)

Opportunistic replacement scheduling with interval costs

The topic of this talk is replacement scheduling in a multicomponent system, where maintenance is associated with a set up or fixed cost. In such a system, replacing several components simultaneously is less expensive than replacing the components at different times. Hence, the replacement of one component is also an opportunity for the replacement of another. We have developed a 0-1 integer linear programming (ILP) model for the problem of scheduling replacement activities when the cost of the schedule depends on the length between replacements. In this model, the integrality restrictions on most variables can be relaxed without losing integrality, and the inequality constraints are facets of the convex hull of feasible solutions. We present numerical tests performed on the replacement scheduling of a turbine in an aircraft engine. We show that the ILP model can be utilized for the two-objective problem of minimizing the replacement cost and minimizing the probability of unexpected system halts. Further, by assigning a cost to unexpected system halts, we also use the ILP model for solving the problem of minimizing the expected cost.

Mahmut Gokce, Izmir University of Economics (with Burak Gokgur, Selin Özpeynirci)

Scheduling for disassembly systems

Disassembly systems obtain valuable parts from end-of-life products to remanufacture, reuse or recycle them. This study deals with the disassembly scheduling and presents a mixed integer programming (MIP) model. Disassembly scheduling is the problem of determining quantity and schedule of items disassembled, held in inventory, sold, and incinerated on which resource over a planning horizon while satisfying at least the service level. The model presented includes a number of novelties including consideration of capacitated resources, environmental concepts and demand for items at all levels. Results from an experimental design are presented. After the statistical analysis of experimentation, research may be directed to develop exact algorithms or heuristics. Insights into the optimal solutions and alternative solution methods to large sized problems with which mathematical programming model has difficulty solving in acceptable times are discussed.

Integer & mixed-integer programming

Wed.2.H 2032

Polyhedral theory

Organizer/Chair Quentin Louveaux, University of Liège · Invited Session

Carla Michini, Sapienza Università di Roma (with Gerard Cornuéjols, Giacomo Nannicini)

How tight is the corner relaxation? Insights gained from the stable set problem

The corner relaxation of a mixed-integer linear program is a central concept in cutting plane theory. In a recent paper Fischetti and Monaci provide an empirical assessment of the strength of the corner and other related relaxations on benchmark problems. In this work we validate with theoretical arguments the empirical results obtained by Fischetti and Monaci: we give a precise characterization of the bounds given by the corner relaxation and three of its extensions, in the special case of the edge formulation of the stable set problem, for which a full description of the corner polyhedron is available. Our theoretical analysis shows that degeneracy plays a major role, as the difference in the bounds given by corner relaxations from two different optimal bases can be significantly large. Therefore, exploiting multiple degenerate bases for cut generation could give better bounds than working with just a single basis.

Laurent Poirrier, University of Liège (with Quentin Louveaux, Domenico Salvagnin)

The strength of multi-row models

We consider the question of how to generate cutting planes from arbitrary multi-row mixed-integer relaxations. In general, these cutting planes can be obtained by row generation, i.e. solving a ("master") LP whose constraint are iteratively constructed by solving ("slave") MIPs. We show how to reduce the size of both problems by adopting a two-phases approach exploiting the bounds on variables and performing sequential lifting whenever possible. We use these results to implement a separator for arbitrary multi-row mixed-integer relaxations and perform computational tests in order to evaluate and compare the strength of some important multi-row relaxations.

Mahdi Doostmohammadi, University of Aveiro (with Agostinho Agra, Quentin Louveaux)

Valid inequalities for the single arc design problem with set-ups

We consider a variant of the classical single node fixed-charge net-

work set with constant capacities in which the capacity of the node is an integer multiple of some constant value. This set is a generalization of the single arc design set studied by Magnanti et al. (1993). It arises in lot-sizing and network design problems. We derive several families of facet-defining inequalities. In particular we generalize the residual capacity inequalities. Then we lift some of these valid inequalities through simultaneous lifting.

Integer & mixed-integer programming

Wed.2.H 2033

Lattices and integer programming

Organizer/Chair Karen Aardal, Delft University of Technology · Invited Session

Karen Aardal, Delft University of Technology (with Frederik von Heymann, Andrea Lodi, Laurence Wolsey)

The structure of LLL-reduced kernel lattice bases: background and outline of the main result

The so-called lattice reformulation of an integer program has been used to solve very hard instances. In this reformulation one expresses the vector of variables in terms of an integer linear combination of kernel lattice basis vectors. Most of the instances tackled so far have been extremely hard even in lower dimensions, so almost all of the computational experience so far is obtained for such instances. When solving larger instances one can observe a certain structure of the reduced kernel lattice bases. More specifically, a lattice basis will contain an identity matrix as a submatrix. This means that some of the variables will have a “rich” translation in terms of the lattice basis vectors, and that the other variables will be merely variable substitutions. In this presentation we address the theoretical reason for the structure to form. We give the necessary background and outline the main ingredients of the theoretical analysis.

Frederik von Heymann, TU Delft (with Karen Aardal, Andrea Lodi, Laurence Wolsey)

The structure of LLL-reduced kernel lattice bases: Theoretical details

This presentation is continuation of the previous one. Here we go in more detail on how the various parts of the analysis are derived, and present several of the proofs. The key ingredient in our analysis is the result that, after a certain number of iterations, the LLL-algorithm, with high probability, only performs size reductions and no swaps. In our derivation we use an inequality derived by Azuma, as well as some Jensen-type inequalities. We illustrate our results computationally.

Andrea Lodi, University of Bologna (with Karen Aardal, Frederik von Heymann, Laurence Wolsey)

On cutting planes and lattice reformulations

Lattice reformulations have been traditionally used to deal with Integer Programming problems that are difficult to solve by branching on variables. We discuss full and/or partial lattice reformulations performed with the aim of generating cutting planes, which are then mapped back in the original space of variables.

Life sciences & healthcare

Wed.2.MA 376

(Next generation) sequences

Organizers/Chairs Gunnar Klau, CWI; Alexander Schönhuth, Centrum Wiskunde & Informatica, Amsterdam · Invited Session

Stefan Canzar, Johns Hopkins University (with Sandro Andreotti, Gunnar Klau, Knut Reinert, David Weese)

Transcriptome reconstruction using delayed column generation

Through alternative splicing, fragments of an RNA transcript of a gene, the exons, are recombined in different ways to generate different mRNA molecules, which in turn code for proteins. Determining the set of transcript variants and their abundance from millions of short sequence reads from the RNA complement of a cell is referred to as the transcriptome reconstruction problem. The main difficulty is that different mRNA variants transcribed from the same gene may share a considerable fraction as a common subsequence. Deciding from which variant a short read originates can thus be intricate and has to be done interdependently, based on the global information provided by high-throughput transcriptome sequencing data.

We present an algorithm that implicitly explores the entire space of all possible transcriptomes by using a delayed column generation approach. We show that the pricing problem is a variant of the longest path problem in directed acyclic graphs, which we can solve efficiently.

Tobias Marschall, Centrum Wiskunde & Informatica (with Markus Bauer, Stefan Canzar, Ivan Costa, Gunnar W. Klau, Alexander Schliep, Alexander Schönhuth)

CLEVER: Clique-enumerating variant finder

Next-generation sequencing techniques have for the first time fa-

cilitated a large scale analysis of human genetic variation. However, despite the advances in sequencing speeds, achieved at ever lower costs, the computational discovery of structural variants is not yet standard. It is likely that a considerable amount of variants have remained undiscovered in many sequenced individuals. Here we present a novel internal segment size based approach, which organizes all, including also concordant reads into a read alignment graph where max-cliques represent maximal contradiction-free groups of alignments. A specifically engineered algorithm then enumerates all max-cliques and statistically evaluates them for their potential to reflect insertions or deletions (indels). We achieve highly favorable performance rates in particular on indels of sizes 30–500 bp and predict a considerable amount of correct, but so far undiscovered variants.

Susanne Pape, FAU Erlangen-Nürnberg, Discrete Optimization (with Alexander Martin)

Computational complexity of the multiple sequence alignment problem

During the last decades, continuing advances in molecular bioinformatics (for example the Human Genome Project) have led to increased information about biological sequences like protein or DNA sequences. Multiple alignments of these sequences play an important role in detecting conserved subregions, inferring evolutionary history, or predicting protein structure and function. We study the computational complexity of two popular problems in multiple sequence alignment: multiple alignment with SP-score and multiple tree alignment - two problems that have indeed received much attention in biological sequence comparison. From a mathematical point of view, both problems are difficult to solve and often remain hard, even if we restrict the problems to instances with scoring matrices that are a metric, a binary alphabet, or a gap-0-alignment (i.e. sequences can be shifted relative to each other, but no internal gaps are allowed). Here, we give an overview of some recent results about NP-completeness and Max-SNP-hardness, analyze the computational complexity of some restricted versions of this problem, and present some new complexity and approximation results.

Logistics, traffic, and transportation

Wed.2.H 0104

TomTom routing and traffic research: Data, models and algorithms

Chair Heiko Schilling, TomTom International B.V.

Heiko Schilling, TomTom International B.V.

TomTom Navigation – How mathematics help getting through traffic faster

TomTom is the leading global supplier of in-car location and navigation content and applications. We are focused on providing drivers with the best possible navigation experience to help them get through traffic faster from A to B. Our navigation applications can already significantly reduce the journey times for individual TomTom drivers but we believe we can help to reduce traffic congestion for all. In this talk we will give examples where we were able to successfully apply results of mathematical research in our navigation applications. Our applications are based on TomTom’s navigation software tool kit – called NavKit – which is built upon 20 years of routing and navigation know-how.

Felix König, TomTom International B.V.

Crowd-sourcing in navigation – How selfish drivers help to reduce congestion for all

In order to help users beat congestion, TomTom’s connected navigation systems receive traffic information in real time. Simultaneously, they function as traffic sensors, frequently and anonymously transmitting speed probes.

After a brief overview of some crowd-sourced traffic data, we will look at a scenario where routes are planned server-side and can hence be coordinated. We will sketch relevant models and results from algorithmic game theory. We will conclude with some research challenges and their practical relevance.

Arne Kesting, TomTom International B.V.

The dynamics of traffic jams – How data and models help to understand the principles behind

Traffic jams are an undesirable result of our individual motor car traffic. From a scientific point of view, however, traffic congestions reveal rich collective dynamics in space and time. Based on empirical data, we will summarise qualitative and quantitative aspects of traffic jam propagation and show how to describe and simulate them with mathematical models. Recent findings suggest that traffic instabilities are of the convective type. Understanding the principles of traffic jams may help us to realize TomTom’s Manifesto – reducing traffic congestion for all.

Logistics, traffic, and transportation

Wed.2.H 0106

Math programming in supply chain applications

Organizer/Chair Pavithra Harsha, IBM Research · Invited Session

Paat Rusmevichientong, University of Southern California (with Huseyin Topaloglu)

Robust assortment optimization

We study robust formulations of assortment optimization problems under the multinomial logit choice model. The true parameters of the logit model are assumed to be unknown, and we represent the set of likely parameter values by a compact uncertainty set. The objective is to find an assortment that maximizes the worst case expected revenue over all parameter values in the uncertainty set. We give a complete characterization of the optimal policy in both settings, show that it can be computed efficiently, and derive operational insights. We also propose a family of uncertainty sets that enables the decision maker to control the tradeoff between increasing the average revenue and protecting against the worst case scenario. Numerical experiments show that our robust approach, combined with our proposed family of uncertainty sets, is especially beneficial when there is significant uncertainty in the parameter values.

Maxime Cohen, MIT (with Ruben Lobel, Georgia Perakis)

Designing consumer subsidies with industry response for green technology adoption

The recent developments in green technologies would not have been possible without the subsidies offered by the government to consumers. While the government designs subsidies to stimulate adoption of new technologies, the manufacturing industry responds to these policies with the goal to maximize profits. In this talk, we study how government should set subsidies when considering the industry's response. More specifically, the supplier adjusts its production quantities and price depending on the level of subsidies offered by the government. In this setting, we expand the understanding of the price-setting newsvendor model, incorporating the external influence from the government who is now an additional player. We consider a model with a general demand function and quantify how uncertainty impacts the system relative to ignoring stochasticity and considering an average case analysis. By assuming that the deterministic part of the demand is a non-increasing and convex function of the effective price, we show that when demand uncertainty increases, quantities produced are higher whereas prices and supplier's profits are lower. Finally, we study the efficiency of this supply chain.

Pavithra Harsha, IBM Research (with Ramesh Natarajan, Dharmashankar Subramanian)

Demand-response in the electricity smart grid: A data-driven pricing and inventory optimization approach

Demand response schemes based on dynamic pricing are of considerable interest in the emerging smart grid. For instance, an electric utility can optimize its operational objectives by providing certain "price incentive signals" to consumers, so as to minimize generation, spinning reserve and salvage costs, and revenue shortfalls, while simultaneously satisfying the resulting stochastic responsive demand. Although perhaps not well known and widely used, this demand-management problem can be formulated as a classical price-sensitive, newsvendor model, but with several enhancements to make it applicable to the smart grid context. A major concern is the interaction of multiple drivers of demand, including weather, time-of-day, and seasonality, in addition to the type and form of the incentive signals. We consider a novel approach that is based on the use of quantile and mixed quantile regression to jointly estimate the optimal stocking level and pricing signals. This approach is data-driven, distribution-free, and makes best use of the sparse, high-dimensional demand data. We illustrate its efficacy, robustness and accuracy over possible alternatives with computational examples.

Logistics, traffic, and transportation

Wed.2.H 0111

New algorithms for new pricing models

Organizer/Chair Hamid Nazerzadeh, Marshall School of Business · Invited Session

Luis Briceño-Arias, Universidad Tecnico Federico Santa Maria (with José Correa)

Optimal continuous pricing with strategic consumers

An interesting problem in mechanism design is that of finding mechanisms to sell a single item when the number of bidders is random. In this paper we take a step further to the static situation and derive an optimal pricing scheme when selling a single item to strategic consumers that arrive over time according to a random process. Combining auction theory and recent work on pricing with strategic consumers, we

derive the optimal pricing mechanism in this situation under reasonable conditions.

Ashish Goel, Stanford University (with Bahman Bahmani, Goel Dandekar, Ramesh Govindan, Ian Post, Michael Wellman, Bryce Wiedenbeck)

Reputation and trust in social networks

Automated reputation and trust systems play an ever increasing role in the emerging networked society. We will first describe a model of networked trust that functions by exchange of IOUs among nodes. Informally, every node acts as a bank and prints its own currency, which is then used to purchase services within the network. Such "trust networks" are robust to infiltration, since any node only accepts currency printed by other nodes that it directly trusts. We will analyze the liquidity of this model, i.e., the number of transactions that such a network can support. We will show that in many interesting cases, the liquidity of these trust networks is comparable to a system where currency is issued by a single centralized bank. We will then show that in simple networks, rational agents allocate trust in a socially optimal manner.

Azarakhsh Malekian, Massachusetts Institute of Technology (with saeed alaei, hu fu, nima haghpanah, jason hartline)

Bayesian optimal auctions via multi- to single-agent reduction

We study an abstract optimal auction problem for a single good or service. This problem includes environments where agents have budgets, risk preferences, or multi-dimensional preferences over several possible configurations of the good (furthermore, it allows an agent's budget and risk preference to be known only privately to the agent). These are the main challenge areas for auction theory. A single-agent problem is to optimize a given objective subject to a constraint on the maximum probability with which each type is allocated, a.k.a., an allocation rule. Our approach is a reduction from multi-agent mechanism design problem to collection of single-agent problems. We focus on maximizing revenue, but our results can be applied to other objectives (e.g., welfare). An optimal multi-agent mechanism can be computed by a linear/convex program on interim allocation rules by simultaneously optimizing several single-agent mechanisms subject to joint feasibility of the allocation rules.

Mixed-integer nonlinear programming

Wed.2.MA 041

Structured MINLP and applications

Organizer/Chair Noam Goldberg, Mathematics and Computer Science Division, Argonne National Laboratory · Invited Session

Toni Lastusilta, GAMS Software GmbH (with Michael R. Busisiek, Stefan Emet)

Chromatographic separation using GAMS extrinsic functions

In chemical and pharmaceutical industries the problem of separating products of a multicomponent mixture can arise. The objective is to efficiently separate the mixture within reasonable costs during a cyclic operation. To optimize the process a boundary value problem that includes differential equations needs to be solved. The presented Mixed-Integer NonLinear Programming (MINLP) model solves an instance of the chromatographic separation process in GAMS by using extrinsic functions. The function library facility that was recently introduced in GAMS 23.7 provides a convenient way of modeling it. The problem has been earlier studied in "Comparisons of solving a chromatographic separation problem using MINLP methods" by Stefan Emet and Tapio West-erlund.

Noam Goldberg, Mathematics and Computer Science Division, Argonne National Laboratory (with Sven Leyffer, Ilya Safro)

Cover inequalities for nearly monotone quadratic MINLPs

Cover Inequalities for nearly monotone quadratic MINLPs We consider MINLPs arising from novel network optimization formulations with a quadratic objective and constraints that satisfy relaxed monotonicity conditions. We derive valid cover inequalities for these formulations and their linearized counterparts. We study heuristics for generating effective cuts in practice and also consider approximate separation in some cases.

Susan Margulies, Pennsylvania State University (with Shmuel Onn)

Hilbert's Nullstellensatz and the partition problem: An infeasibility algorithm via the partition matrix and the partition polynomial

Given a set of integers W , the partition problem determines whether or not W can be partitioned into two disjoint sets with equal sums. In this talk, we model the partition problem as a system of polynomial equations, and then investigate the complexity of the Hilbert's Nullstellensatz refutations, or certificates of infeasibility, when the underlying set of integers W is non-partitionable. We present an algorithm for finding lower bounds on the degree of Hilbert Nullstellensatz refutations, and survey a known result on the complexity of independent set Nullstellensatz certificates. We then describe a method for extracting a square

matrix from the combination of Hilbert's Nullstellensatz and the partition problem, and demonstrate that the determinant of that matrix is a polynomial that factors into an iteration of all possible partitions of W .

Mixed-integer nonlinear programming

Wed.2.MA 042

Topics in mixed-integer nonlinear programming II

Chair Michael Engelhart, Interdisciplinary Center for Scientific Computing (IWR), Uni Heidelberg

Melania Călinescu, VU University Amsterdam (with Sandjai Bhulai, Barry Schouten)

Optimal resource allocation in survey designs

Resource allocation is a relatively new research area in survey designs and has not been fully addressed in the literature. Survey organizations across the world are considering the development of new mathematical models in order to improve the quality of survey results while taking into account optimal resource planning.

The resource allocation problem for survey designs has specific features that lead to a formulation as a nonconvex integer nonlinear problem, which prohibits the application of many algorithms that are found in the literature. Current global optimization tools that address general nonconvex integer problems suffer from long computational times and limitations in the problem size. Moreover, implementing solutions from convex approximations of the problem may result in major errors in survey results.

We present an algorithm that solves the problem to optimality using Markov decision theory. Additionally to optimal resource planning, the algorithm can handle various practical constraints that aim at improving the quality of survey results. The algorithm is implemented in C++, it achieves short computational times and it can handle large-scaled problems.

Michael Engelhart, Interdisciplinary Center for Scientific Computing (IWR), Uni Heidelberg (with Joachim Funke, Sebastian Sager)

A new test-scenario for analysis and training of human decision making with a tailored decomposition approach

In the research domain *complex problem solving* in psychology, where the aim is to analyze complex human decision making and problem solving, computer-based test-scenarios play a major role. The approach is to evaluate the performance of participants within *microworlds* and correlate it to certain attributes, e.g., the participant's capacity to regulate emotions. In the past, however, these test-scenarios have usually been defined on a trial-and-error basis to realize specific requirements for the testee. The more complex models become, the more likely it is that unforeseen and unwanted characteristics emerge in studies. To overcome this important problem, we propose to use mathematical optimization methodology on three levels: first, in the design stage of the complex problem scenario, second, as an analysis tool, and third, to provide feedback in real time for learning purposes. We present a novel test scenario, the *IWR Tailorshop*, with functional relations and model parameters that have been formulated based on optimization results, as well as a tailored decomposition approach to address the resulting nonconvex nonlinear mixed-integer programs.

Multi-objective optimization

Wed.2.H 1029

Nonlinear multiobjective optimization

Chair Shashi Mishra, Banaras Hindu University

Shashi Mishra, Banaras Hindu University (with Vivek Laha, Vinay Singh)

On constraint qualifications in multiobjective optimization problems with vanishing constraints

In this paper, we consider the class of multiobjective optimization problems (MOP) called as multiobjective optimization problems with vanishing constraints (MOPVC). For the scalar case the (MOPVC) reduces to a mathematical program with vanishing constraints (MPVC) recently appeared in literature. We introduce a suitable representation of the linearizing cone of the MOPVC and use it to define generalized Guignard constraint qualification (GGCQ) for the MOPVC. We derive Karush-Kuhn-Tucker type necessary optimality conditions for efficiency in the MOPVC under the assumption that the GGCQ for the MOPVC holds. We also introduce several modifications of some known constraint qualifications like Abadie constraint qualification, Cottle constraint qualification, Slater constraint qualification, linear objective constraint qualification, Mangasarian-Fromovitz constraint qualification, linear independence constraint qualification and linear constraint qualification for the

MOPVC and establish relationships among various constraint qualifications which ensure that GGCQ holds for the MOPVC.

Ingrida Steponavice, University of Jyväskylä (with Kaisa Miettinen)

On robustness for simulation-based multiobjective optimization

Many real-world engineering design problems are too complex to be modeled analytically and involve the use of computer simulations. In simulation-based applications, performance of a system is evaluated based on the output from a simulation model which is typically subject to various sources of uncertainty. In design optimization, the designer or the decision maker may prefer a robust solution which is as "good" as possible and at the same time leads to small performance variations that appear due to uncertainty. Robustness in this context is understood as an insensitivity of objective functions values to some uncertainty arising due to stochastic processes inside the simulation model. We survey the approaches for robust simulation-based multiobjective optimization proposed in the literature and discuss the multiobjective robustness measures that can be used to find robust solutions.

Luis Lucambio Perez, Federal University of Goiás (with Jose Yunier Bello Cruz)

A modified subgradient algorithm for solving K -convex inequalities

Thirty years ago, Robinson proposed a subgradient method for solving K -convex inequalities in finite dimensional spaces. In this work, we propose a modification of this method that allows to solve systems of K -convex inequalities in Hilbert spaces, and has two advantages: first, without additional hypotheses, it was possible to show that it converges strongly to a solution of the problem, and second, it has the desirable property that the limit point is the closest solution to the starting point. To prove that our algorithm is well defined it was necessary to show that the set of sub-gradients is non-empty at interior points of the domain. We demonstrate this fact when the cone K is finitely generated. To our knowledge, this is the first time it is proved the existence of such sub-differentials of vectorial K -convex functions in infinite dimensional spaces.

Nonlinear programming

Wed.2.H 0107

Regularization techniques in optimization II

Organizer/Chair Jacek Gondzio, University of Edinburgh - Invited Session

Stefania Bellavia, Università di Firenze (with Benedetta Morini)

Regularized Euclidean residual algorithm for nonlinear least-squares with strong local convergence properties

This talk deals with Regularized Euclidean Residual methods for solving nonlinear least-squares problems of the form:

$$\min_x \|F(x)\|^2$$

where $F: \mathbb{R}^n \rightarrow \mathbb{R}^m$. Any relationship between n and m is allowed. This approaches use a model of the objective function consisting of the un-squared Euclidean residual regularized by a quadratic term. The role of the regularization term is to provide global convergence of these procedure without the need to wrap them into a globalization strategy. We will show that the introduction of the regularization term also allow to get fast local convergence to roots of the underlying system of nonlinear equations, even if the Jacobian is not full rank at the solution. In fact, they are locally fast convergent under the weaker condition that $\|F\|$ provides a local error bound around the solution. In particular, in case $m \geq n$, this condition allows the solution set to be locally nonunique. Some numerical results are also presented.

Benedetta Morini, Università di Firenze (with Stefania Bellavia, Valentina de Simone, Daniela di Serafino)

Preconditioning of sequences of linear systems in regularization techniques for optimization

We build preconditioners for sequences of linear systems

$$(A + \Delta_k)x_k = b_k, \quad k = 1, 2, \dots,$$

where $A \in \mathbb{R}^{n \times n}$ is symmetric positive semidefinite and sparse, $\Delta_k \in \mathbb{R}^{n \times n}$ is diagonal positive semidefinite and the systems are compatible. Such sequences arise in many optimization methods based on regularization techniques: trust-region and overestimation methods for nonlinear least-squares, regularized affine-scaling methods for convex bound-constrained quadratic programming and bound-constrained linear least-squares.

We propose a framework for updating any symmetric positive definite preconditioner for A , factorized as LDL^T . The resulting preconditioners are effective on slowly varying sequences and cluster eigenvalues of the preconditioned matrix when Δ_k has sufficiently large entries. We discuss two preconditioners in this framework and show their efficiency on sequences of linear systems arising in the solution of non-

Nonsmooth optimization

linear least-squares problems and bound-constrained convex quadratic programming.

Serge Gratton, IRIT-CERFACS (with Selime Gurof, Philippe Toint, Jean Tshimanga)

Preconditioning inverse problems using duality

The problem considered in this talk is the data assimilation problem arising in weather forecasting and oceanography, which consists in estimating the initial condition of a dynamical system whose future behaviour is to be predicted. More specifically, new optimization techniques will be discussed for the iterative solution of the particular non-linear least-squares formulation of this inverse problem known under the name of 4DVAR, for four-dimensional data assimilation. These new methods are designed to decrease the computational cost in applications where the number of variables involved is expected to exceed 10^9 . They involve the exploitation of the problem's underlying geometrical structure in reformulating standard trust-region techniques into significantly cheaper variants. Adapted preconditioning issues for the considered systems of equations will be discussed, which also depend on the problem's geometrical structure and which exploit limited-memory techniques in a novel way.

Nonlinear programming

Wed.2.H 0112

Applications of optimization I

Chair Marc Steinbach, Leibniz Universität Hannover

Makoto Yamashita, Tokyo Institute of Technology (with Zih-Cin Lin, I-Lin Wang)

An approach based on shortest path and connectivity consistency for sensor network localization problems

Sensor network localization (SNL) problems are considered to be an important topic due to the variety of applications including a molecular conformation. In SNL problems, we have anchors (known locations) and sensors (unknown locations). The distance between a pair of them is available if the pair is closer than the radio range. From this partial distance information, we want to infer the sensor locations. SDP relaxation approaches often generate high quality solution, but their computation cost can easily grow up for large SNLs. To solve SNLs with a cheaper cost, we combine several heuristics. We first compute the shortest paths from anchors to sensors hopping some sensors. For each sensor, we use the path lengths to guess its location roughly. After applying a gradient method, we adjust the sensors based on connectivity consistency. When a pair should be closer than the radio range, but the computed distance is longer than it, we 'pull' the sensor locations. We repeat the shortest path and the adjustment, until we fix all the sensors as reliable. Numerical results show that this approach obtains the sensor locations with relatively good accuracy using low computation cost.

Michael Patriksson, Chalmers University of Technology (with Christoffer Strömberg)

Nonlinear continuous resource allocation - A numerical study

We study the performance of the most important algorithms for solving the strictly convex and separable resource allocation problem. This singly constrained problem arises in many applications, particularly as a subproblem, whence the search for extremely efficient solution procedures for the problem continues. We compare the performance of algorithms belonging to the relaxation, breakpoint and quasi-Newton classes of methods, for sizes up to about 100 Million variables, establishing that a new implementation of a relaxation algorithm utilizing a blended evaluation of the relaxed problem performs the best in general, having linear practical convergence even for very many variables.

Marc Steinbach, Leibniz Universität Hannover

Estimating material parameters by X-ray diffraction

X-ray diffraction is a standard method for quantitative material analysis in areas like crystallography, chemistry, or biochemistry: X-Ray exposure yields intensity distributions that depend on the molecular structure and that can be measured with high precision over a certain range of diffraction angles. Material parameters are then obtained by suitable parameter estimation methods. The talk presents the resulting class of typically ill-conditioned constrained inverse problems and reports on the development and implementation of a real time solution algorithm. Main components of the algorithm include a Levenberg-Marquardt method, a truncated CG method featuring certain projection techniques, and sparse linear algebra exploiting the specific Jacobian structure. The post-optimality analysis includes a detection of modeling redundancy and a covariance computation based on an SVD or a QR decomposition with pivoting.

Wed.2.H 1012

Applications of nonsmooth optimization

Chair Amirhossein Sadoghi, Frankfurt School of Finance & Management

Ann-Brith Strömberg, Chalmers University of Technology (with Emil Gustafsson, Torbjörn Larsson, Magnus Önnheim, Michael Patriksson)

Lagrangian optimization for inconsistent linear programs

When a Lagrangian dual method is used to solve an infeasible optimization problem, the inconsistency is manifested through the divergence of the dual iterates. Will the primal sequence of subproblem solutions still yield relevant information about the primal solution? We answer this question in the affirmative for a linear program and an associated Lagrangian dual algorithm. We show that the primal-dual linear program can be associated with a saddle point problem in which - in the inconsistent case - the primal part amounts to finding a solution in the primal space such that the total amount of infeasibility in the relaxed constraints is minimized; the dual part aims to identify a steepest feasible ascent direction. We present convergence results for a subgradient optimization algorithm applied to the Lagrangian dual problem, and the construction of an ergodic sequence of primal subproblem solutions; this algorithm yields convergence to a saddle point. We establish that the primal sequence finitely converges to a minimizer of the original objective over the primal solutions of the saddle-point problem, while the dual iterates diverge in the direction of steepest ascent.

Adilson Xavier, Federal University of Rio de Janeiro (with Claudio Gesteira, Vinicius Xavier)

The continuous multiple allocation p -hub median problem solving by the hyperbolic smoothing approach: Computational performance

Hub-and-spoke (HS) networks constitute an important approach for designing transportation and telecommunications systems. The continuous multiple allocation p -hub median problem consists in finding the least expensive HS network, locating a given number of p hubs in planar space and assigning traffic to them, given the demands between each origin-destination pair and the respective transportation costs, where each demand center can receive and send flow through more than one hub. The specification of the problem corresponds to a strongly non-differentiable min-sum-min formulation. The proposed method overcomes this difficulty with the hyperbolic smoothing strategy, which has been proven able to solve large instances of clustering problems quite efficiently. The solution is ultimately obtained by solving a sequence of differentiable unconstrained low dimension optimization subproblems. The consistency of the method is shown through a set of computational experiments with large hub-and-spoke problems in continuous space with up to 1000 cities. The quality of the method is shown by comparing the produced solutions with that published in the literature.

Amirhossein Sadoghi, Frankfurt School of Finance & Management (with Oleg Burdakov, Anders Grimval)

Piecewise monotonic regression algorithm for problems comprising seasonal and monotonic trends

We consider piecewise monotonic models for problems comprising seasonal cycles and monotonic trends. In contrast to the conventional piecewise monotonic regression algorithms, our algorithm can efficiently exploit a priori information about temporal patterns. Our approach is based on establishing monotonic relations between the observations that compose the data set. These relations make the data set partially ordered, and allows us to reduce the original data fitting problem to a monotonic regression problem under the established partial order. The latter is a large-scale convex quadratic programming problem. It is efficiently solved by the recently developed Generalized Pool-Adjacent-Violators (GPAV) algorithm.

Optimization in energy systems

Wed.2.MA 549

Robust aspects of optimization in energy management

Organizer/Chair Wim van Ackooij, EDF R&D - Invited Session

Wim van Ackooij, EDF R&D (with René Henrion, Claudia Sagastizabal)

Decomposition methods for unit-commitment with coupling joint chance constraints

An important optimization problem in energy management, known as the "Unit-Commitment Problem", aims at computing the production schedule that satisfies the offer-demand equilibrium at minimal cost. Often such problems are considered in a deterministic framework. However uncertainty is present and non-negligible. Robustness of the production schedule is therefore a key question. In this paper, we will investigate this robustness when hydro valleys are made robust against uncertainty on inflows, by using bilateral joint chance constraints. Moreover, we will make the global schedule robust, by using a bilateral joint chance constraint for the offer-demand equilibrium constraint. Since

this is a fairly big model, we will investigate several decomposition procedures and compare these on a typical numerical instance. We will show that an efficient decomposition schedule can be obtained.

Andris Müller, Weierstrass Institute Berlin (WIAS) (with René Henrion, Wim Van Ackooij, Riadh Zorgati)
Probabilistic programming in power production planning

Power production planning applications depend on stochastic quantities like uncertain demand, uncertain failure rates and stochastic inflow into water reservoirs, respectively. To deal with the stochastic behaviour of these quantities we consider optimization problems with joint probabilistic constraints of the type

$$\min_x \{c^T x \mid P(A(x)\xi \leq b(x)) \geq p, x \in X\}$$

where $p \in (0, 1)$ is the required probability level.

The treatment of this optimization problem requires the computation of function values and gradients of $\varphi(x) := P(A(x)\xi \leq b(x))$. We will present derivative formulae for special cases which extend a classical result (see Prekopa 1995). As in the classical result the derivative formulae reduces the computation of gradients to the computation of function values again. Thus the same existing codes may be used to compute $\varphi(x)$ and $\nabla\varphi(x)$.

Numerical results for selected power production applications will be reported.

Raimund Kovacevic, University of Vienna (with Alois Pichler)

A process distance approach for scenario tree generation with applications to energy models

We develop algorithms to construct tree processes which are close to bigger trees or empirical or simulated scenarios and can e.g., be used for multistage stochastic programming. Our approach is based on a distance concept for stochastic processes, developed in Pflug and Pichler (2011): The process-distance used is based on the process' law, accounts for increasing information over time and generalizes the Wasserstein distance, which itself is a distance for probability measures. In this framework we implement an algorithm for improving the distance between trees (processes) by changing the probability measure and the values related to the smaller tree. In addition we use the distance for stepwise tree reduction. Algorithms are applied to energy prices, leading to tree based stochastic programs in the area of electricity industry, involving e.g., electricity, oil and gas spot prices.

Optimization in energy systems

Wed.2.MA 550

Stochastic optimization applied to power systems

Organizer/Chair Sara Lumbreras, Institute for Research in Technology (IIT), Universidad Pontificia Comillas · Invited Session

Sara Lumbreras, Institute for Research in Technology (IIT), Universidad Pontificia Comillas (with Santiago Cerisola, Andrés Ramos)

Efficient incorporation of contingency scenarios to stochastic optimization. Application to power systems.

Many design problems include reliability as a sub-objective, which is evaluated through contingency scenarios. In particular, power system design problems usually incorporate reliability considerations of this kind in generation expansion or transport expansion problems. The incorporation of these scenarios to a stochastic optimization problem results in a special structure where each scenario is linked to the failure of a specific available component. We propose a Progressive Contingency Algorithm (PCI) to exploit this structure. This methodology is applied to the optimization of the electrical layout design of an offshore wind farm in a real case study. Time savings reached two orders of magnitude.

Santiago Cerisola, Universidad Pontificia Comillas (with Sara Lumbreras, Andres Ramos)

Approximations of recourse functions in hydrothermal models. Numerical experiences.

In this exposition we present some results about the application of stochastic programming techniques to a multistage hydrothermal model. We give an overview of extensions to use binary variables at every stage and to use it for nonconvex models. Our current experiments of application of approximation techniques to the model are presented. We take advantage of the convexity and monotonicity of the recourse function in the computation of the expected recourse function and in its approximation in a Benders type algorithm. Standard integration techniques are employed that involve the calculation of lower and upper bounds.

Francisco Munoz, Johns Hopkins University (with Benjamin Hobbs)

Using decomposition methods for wide-area transmission planning to accommodate renewables: A multi-stage stochastic approach

Increasing environmental concerns have led authorities to promote the use of generation from renewable technologies. Although the type

and location of future generation investments are still uncertain, transmission planners still need to make decisions "today", in order to have enough network infrastructure available for "tomorrow". Consequently, there is a need for tools to aid transmission planners to select robust transmission plans that will accommodate a broad range of generation configurations. We developed a two-stage stochastic program that considers transmission lumpiness, generators' response, uncertainty and Kirchhoff Voltage Laws. We apply our methodology to a 17-bus representation of California, and a 240-bus representation of the Western Interconnection in the US. We discuss the implementation and performance of Benders decomposition as an alternative approach for large-scale networks.

PDE-constrained opt. & multi-level/multi-grid meth.

Wed.2.MA 415

Optimization applications in industry IV

Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics · Invited Session

Hans Josef Pesch, University of Bayreuth (with Kurt Chudej, Armin Rund, Kati Sternberg)

Direct versus indirect solution methods in real-life applications: Load changes of fuel cells

When analyzing mathematical models for complex dynamical systems, their analysis and numerical simulation is often only a first step. Thereafter, one often wishes to complete these investigations by an optimization step to exploit inherent degrees of freedom. This generally leads to optimization problems of extremely high complexity if the underlying system is described by time dependent partial differential equations (PDEs) or, more generally, by a system of partial differential algebraic equations (PDAEs).

The driving example of this talk is concerned with the optimal control of a fuel cell system. The underlying mathematical model constitutes a high dimensional PDAE system describing the gas transport and the electro-chemical reactions within the fuel cells.

In this talk we will particularly discuss the pros and cons of direct versus indirect methods, resp. first discretize then optimize versus first optimize then discretize when applying these approaches on real-life problems of extremely high complexity.

Chantal Landry, Weierstrass Institute (with Matthias Gerds, René Henrion, Dietmar Hömberg)

Modeling of the optimal trajectory of industrial robots in the presence of obstacles

In automotive industry robots work simultaneously on the same workpiece. They must accomplish their task as fast as possible and without colliding with surrounding obstacles. We model the search of the fastest collision-free trajectory of each robot as a time optimal control problem. The collision avoidance is based on linear programming and expressed as state constraints. The resulting optimal control problem is solved by a sequential quadratic programming method. In order to speed up the resolution an active set strategy based on back-face culling is added. Numerical examples illustrate the efficiency of this strategy.

Jean-Antoine Désidéri, INRIA (with Adrien Zerbinati, Régis Duvigneau)

Multiple gradient descent algorithm (MGDA) for multi-objective optimization with application to compressible aerodynamics

We focus on the development of numerical algorithms for multi-objective optimization, with application to physical systems governed by PDE's. Indeed, concurrent engineering makes multi-objective optimization a particularly acute question in the design of complex systems. In several mature disciplines, modern simulation codes often provide along with the evaluation of the performance, or functional criterion, the calculation of the functional gradient. Assuming the gradients of different criteria are at hand, we propose and analyze systematic constructions of a descent direction common to all criteria. Based on this, MGDA generalizes to multi-objective optimization the classical steepest-descent method. We prove that it converges to Pareto stationary points, and demonstrate the efficiency of the method in several problems: aircraft wing design, shape optimization of an automobile cooling system duct.

Robust optimization

Wed.2.MA 004

Applications of robust optimization IV

Chair Pierre-Louis Poirion, CEDRIC/ENSTA/CNAM

Jorge Vera, Universidad Catolica De Chile (with Pamela Alvarez, Sergio Maturana)

Improving consistency of tactical and operational planning using robust optimization

This work is motivated by a problem in the forest industry, in which

tactical planning is carried out using an optimization model and then short term decisions are taken. It is expected that operational decisions be consistent with tactical plans, but that is not usually the case as the process is subject to various uncertainty, especially those originating in the natural variation of the forest. The “rolling horizon” approach is used in practice as an attempt to reduce inconsistencies, but we propose that using a robust optimization tactical planning model should increase the chances of consistency with the short term. The question, however, is how much robustness do we need, as being robust is expensive, and whether structural characteristics of the problem can be used to anticipate these factors. We provide some specific estimates, like probabilities of consistency, and results on the relations as well as computational results based on an industrial case. We also show how to dynamically adjust the degree of robustness of the planning process in such a way to approach an “optimal” policy. These results should be relevant also in other problems where consistency is desirable.

Florian Bruns, Universität Osnabrück (with Marc Goerigk, Sigrid Knust, Anita Schöbel)

Robust load planning of trains in intermodal transportation

In this paper the problem of robust load planning for trains in intermodal container terminals is studied. The objective is to assign load units (container, swap bodies and trailer) to wagons of a train such that the utilization of the train is maximized, and setup and transportation costs in the terminal are minimized. However, in real-world applications many of the parameters needed for the model are not known exactly.

In our paper we enhance the load planning problem by taking the most important uncertainties into account. Based on a mixed-integer linear programming formulation developed in Bruns and Knust (2010) we are able to formulate robust counterparts and show how these may be solved within a reasonable runtime. Our results indicate that it might be worth to study the robust counterparts even of large and complicated mixed-integer programs.

Pierre-Louis Poirion, CEDRIC/ENSTA/CNAM (with Alain Billionnet, Marie-Christine Costa)

Robust optimal sizing of an hybrid energy stand-alone system

The development of renewable energy brought new complex combinatorial optimization problems as the one studied here: the conception of an autonomous hybrid energy system. The study is made considering a finite time horizon divided into periods where an energy demand has to be fulfilled. An auxiliary fuel generator guarantees to meet the demand in every case but its use induces important costs. The aim is to determine the optimal number of photovoltaic panels, wind turbines and batteries while minimizing the total cost of investment and use. We first propose a mixed integer linear model for the problem without uncertainty. However, the stochastic behavior of both solar and wind energy and of the demand needs to be taken into account for a robust solution: here, we only consider the variation of the demands. We focus on an approach where we assume that the total variation of the demands is bounded. The problem is modeled as a two stage optimization program where the decision variables are integer while the recourse problem is a quadratic continuous program. We show that it can be linearized, which allows us to solve the global robust problem with a constraint generation algorithm.

Sparse optimization & compressed sensing

Wed.2.H 1028

Efficient first-order methods for sparse optimization and its applications

Organizer/Chair Shiqian Ma, University of Minnesota · Invited Session

Shiqian Ma, University of Minnesota

An alternating direction method for latent variable Gaussian graphical model selection

Latent variable Gaussian graphical model selection (LVGGMS) is an important topic in Statistics and Machine Learning. We propose an alternating direction method (ADM) that solves a convex formulation of LVGGMS proposed by Chandrasekaran, Parrilo and Willsky (2010). There are three sets of variables in this convex formulation. Our proposed ADM solves three subproblems that all have closed-form solutions in each iteration, which makes our algorithm very efficient and capable of solving very large problems. The global convergence result of the proposed algorithm is established. Numerical results on both synthetic data and gene expression data are shown to demonstrate the efficiency of the proposed method.

Zhaosong Lu, Simon Fraser University (with Yong Zhang)

Sparse approximation via penalty decomposition methods

In this talk we consider sparse approximation problems, that is, general l_0 minimization problems with the l_0 -“norm” of a vector being a part of constraints or objective function. In particular, we first study the first-order optimality conditions for these problems. We then propose penalty decomposition (PD) methods for solving them in which a

sequence of penalty subproblems are solved by a block coordinate descent (BCD) method. Under some suitable assumptions, we establish that any accumulation point of the sequence generated by the PD methods satisfies the first-order optimality conditions of the problems. Furthermore, for the problems in which the l_0 part is the only nonconvex part, we show that such an accumulation point is a local minimizer of the problems. In addition, we show that any accumulation point of the sequence generated by the BCD method is a saddle point of the penalty subproblem. Moreover, for the problems in which the l_0 part is the only nonconvex part, we establish that such an accumulation point is a local minimizer of the penalty subproblem. Finally, we test the performance of our PD methods by applying them to sparse logistic regression,

Donald Goldfarb, Columbia University (with Bo Huang, Shiqian Ma)

An accelerated linearized Bregman method

We propose and analyze an accelerated linearized Bregman (ALB) method for solving the basis pursuit and related sparse optimization problems. Our algorithm is based on the fact that the linearized Bregman (LB) algorithm first proposed by Stanley Osher and his collaborators is equivalent to a gradient descent method applied to a certain dual formulation. We show that the LB method requires $O(1/\epsilon)$ iterations to obtain an ϵ -optimal solution and the ALB algorithm reduces this iteration complexity to $O(1/\sqrt{\epsilon})$ while requiring almost the same computational effort on each iteration. Numerical results on compressed sensing and matrix completion problems are presented that demonstrate that the ALB method can be significantly faster than the LB method.

Stochastic optimization

Wed.2.MA 141

Scenario generation in stochastic optimization

Organizer/Chair David Papp, Northwestern University · Invited Session

David Papp, Northwestern University (with Sanjay Mehrotra)

Generating moment matching scenarios using optimization techniques

An optimization based method is proposed to generate moment matching scenarios for stochastic programming. The main advantage of the method is its flexibility: it can generate scenarios matching any prescribed set of moments of the underlying distribution rather than matching all moments up to a certain order. The method is based on a semi-infinite linear programming formulation of the problem that is shown to be solvable with polynomial iteration complexity. A practical column generation method is also presented, in which the column generation subproblems are polynomial optimization problems. It is found that the columns in the column generation approach can be efficiently generated by random sampling. The number of scenarios generated matches a lower bound of Tchakaloff's. Empirical results show that the proposed approach outperforms Monte Carlo and quasi-Monte Carlo based approaches on the tested problems.

Teemu Pennanen, King's College London

Tractability of stochastic programs

Recently, Nemirovski et al. established the tractability of a class of convex stochastic programs in the randomized setting. This talk describes classes of convex stochastic programs that are tractable in the stronger, worst case setting.

Jitendra Desai, Nanyang Technological University (with Suvrajeet Sen)

A mathematical programming framework for decision tree analysis

One of the most important analytical tools often used by management executives is decision tree analysis. Traditionally, the solution to decision tree problems has been accomplished using backward recursion or more specifically (stochastic) dynamic programming techniques, but such methods have been shown to suffer from a number of shortcomings. In this research effort, we present a mathematical programming formulation for solving decision tree problems that not only alleviate the difficulties faced by traditional approaches but also allows for the incorporation of new classes of constraints that were hitherto unsolvable in this decision-making context. We begin by presenting a mathematical representation of decision trees as a (path-based) polynomial programming problem, which can be efficiently solved using a branch-and-bound method. Recognizing the exponential increase in problem size for large-scale instances, we extend this basic characterization to a compact path-based relaxation and exploit the special structure of this formulation to design an efficient globally optimal branch-price-and-cut algorithm.

Stochastic optimization

Wed.2.MA 144

Large-scale stochastic programming

Organizer/Chair Mihai Anitescu, Argonne National Laboratory · Invited Session

Andreas Grothey, University of Edinburgh

Multiple-tree interior point method for stochastic programming

We present an interior point based multi-step solution approach for stochastic programming problems, given by a sequence of scenario trees of increasing sizes. These trees can be seen as successively more accurate discretization of an underlying continuous probability distribution. Each problem in the sequence is warmstarted from the previous one. We analyse the resulting algorithm, argue that it yields improved complexity over either the coldstart or a naive two-step scheme, and give numerical results.

Miles Lubin, Massachusetts Institute of Technology (with Mihai Anitescu, J. A. Julian Hall, Kipp Martin, Cosmin Petra, Burhaneddin Sandikçi)

Parallel and distributed solution methods for two-stage stochastic (M)ILPs

Large-scale linear and mixed-integer two-stage stochastic programming problems with recourse with a finite number of scenarios (typically arising from sample average approximation formulations) have been widely studied; however, many instances remain computationally challenging if not intractable on a modern desktop. For such instances, parallel computing holds great potential due to the decomposable nature of the problems. After reviewing the state of the art, we present our recent work on parallelizing the simplex algorithm for deterministic-equivalent form LP problems, thereby obtaining optimal bases for efficient hot starts for branch and bound or real-time control. We present as well a parallelization of a Lagrangian relaxation approach akin to Caroe and Schultz's dual decomposition algorithm with a novel treatment of combining subproblems to decrease the Lagrangian duality gap. Both approaches look towards solving two-stage mixed-integer problems on a massively parallel scale, and we will compare their effectiveness on a stochastic power grid unit commitment problem as well as problems from the literature.

Werner Römisch, Humboldt-University Berlin (with Holger Heitsch, Hernan Leovey)

Are quasi-Monte Carlo methods efficient for two-stage stochastic programs?

Quasi-Monte Carlo algorithms are studied for designing discrete approximations of two-stage linear stochastic programs. Their integrands are piecewise linear, but neither smooth nor of bounded variation in the sense of Hardy and Krause. We show that under some weak geometric condition on the two-stage model all terms of their ANOVA decomposition, except the one of highest order, are smooth if the densities are smooth. Hence, Quasi-Monte Carlo algorithms may achieve the optimal rate of convergence $O(n^{-1+\delta})$ for $\delta \in (0, 1/2)$ and with a constant not depending on the dimension. The geometric condition is generically (i.e., almost everywhere) satisfied if the underlying distribution is normal. We also discuss sensitivity indices, efficient dimensions and suitable transformations to reduce the efficient dimension of two-stage integrands.

Telecommunications & networks

Wed.2.H 3002

Length bounded trees

Organizer/Chair Markus Leitner, Vienna University of Technology · Invited Session

Ivana Ljubic, University of Vienna (with Luis Gouveia, Markus Leitner)

Layered graph models for hop constrained trees with multiple roots

We consider a network design problem that generalizes the hop constrained Steiner tree problem as follows: Given an edge-weighted undirected graph whose nodes are partitioned into a set of root nodes, a set of terminals and a set of Steiner nodes, find a minimum-weight subtree that spans all the roots and terminals so that the number of hops between each relevant node and an arbitrary root does not exceed a given hop limit. The set of relevant nodes may be equal to the set of terminals, or to the union of terminals and root nodes. We first introduce a natural mixed integer programming formulation using edge and node decision variables based on jump cuts. We then propose models utilizing one layered graph for each root node. Possibilities to relate solutions on the layered graphs and additional strengthening inequalities are discussed. Furthermore, theoretical comparisons between these models and previously proposed flow-based and path-based models are given. To solve the problem to optimality, we implement branch-and-cut algo-

ritms for the layered graph formulations. These show clear computational advantages over previously existing approaches.

Markus Leitner, Vienna University of Technology (with Luis Gouveia, Ivana Ljubic)

New models for the diameter constrained steiner tree problem

We consider the diameter constrained minimum Steiner tree problem on a graph (DCSTP). Given an edge-weighted undirected graph whose nodes are partitioned into a set of terminal and Steiner nodes, the objective is to find a minimum-weight subtree that spans all terminal nodes such that the number of hops between any two terminal nodes does not exceed a given diameter D . In this work, we introduce integer linear programming models for the DCSTP based on the concept of triangles, i.e. diameter constrained Steiner trees induced by terminal subsets of size three. Starting from a generic formulation including abstract triangle constraints, we discuss various possibilities of realizing them including multi-commodity, common, and uncommon flows. Furthermore, we propose a model utilizing an exponential set of variables, each corresponding to one feasible triangle. We show, how the linear programming relaxation of this model can be solved by column generation or Lagrangian relaxation. Finally, we study the possibility of further strengthening these models using reformulation by intersection.

Andreas Bley, TU Berlin (with Jannik Matuschke, Benjamin Müller)

Capacitated facility location with length bounded trees

We consider a generalization of the Capacitated Facility Location problem, where clients may connect to open facilities via trees shared by multiple clients. The total demand of clients served by a single tree must not exceed a given tree capacity. Furthermore, the length of the path between a client and its facility within the corresponding tree must not exceed a given length bound. The task is to choose open facilities and shared service trees in such a way that the sum of the facility costs and the tree costs is minimal. This problem arises, for example, in the planning of optical access networks in telecommunications, where multiple clients may share a fiber tree if both fiber capacity and signal attenuation on the resulting connection paths permit.

We show that the problem is as hard as Set Cover in general and approximable with a constant factor for metric edge lengths that individually do not exceed the length bound. For the latter case, we present a general approximation algorithm and discuss several modifications of this algorithm that yield better approximation ratios or additional solution properties in special cases.

Variational analysis

Wed.2.H 2035

Structural properties in variational analysis

Organizer/Chair Stephen Robinson, University of Wisconsin-Madison · Invited Session

Boris Mordukhovich, Wayne State University (with Terry Rockafellar)

Second-Order variational analysis and stability in optimization

We present new results on the second-order generalized differentiation theory of variational analysis with new applications to tilt and full stability in parametric constrained optimization in finite-dimensional spaces. The calculus results concern second-order subdifferentials (or generalized Hessians) of extended-real-valued functions, which are dual-type constructions generated by coderivatives of first-order subdifferential mappings. We develop general second-order chain rules for amenable compositions and calculate second-order subdifferentials for some major classes of piecewise linear-quadratic functions. These results are applied to characterizing tilt and full stability of local minimizers for important classes of problems in constrained optimization that include, in particular, problems of nonlinear programming and certain classes of extended nonlinear programs described in composite terms.

Adrian Lewis, Cornell University (with J. Bolte, A. Daniilidis, D. Drusvyatskiy, and S. Wright)

Active sets and nonsmooth geometry

The active constraints of a nonlinear program typically define a surface central to understanding both theory and algorithms. The standard optimality conditions rely on this surface; they hold generically, and then the surface consists locally of all solutions to nearby problems. Furthermore, standard algorithms "identify" the surface: iterates eventually remain there. A blend of variational and semi-algebraic analysis gives a more intrinsic and geometric view of these phenomena, attractive for less classical optimization models. A recent proximal algorithm for composite optimization gives an illustration.

Shu Lu, University of North Carolina at Chapel Hill

Confidence regions and confidence intervals for stochastic variational inequalities

The sample average approximation (SAA) method is a basic approach for solving stochastic variational inequalities (SVI). It is well known that under appropriate conditions the SAA solutions provide

asymptotically consistent point estimators for the true solution to an SVI. We propose a method to build asymptotically exact confidence regions for the true solution that are computable from the SAA solutions, by exploiting the precise geometric structure of the variational inequalities and by appealing to certain large deviations probability estimates. We justify this method theoretically by establishing a precise limit theorem, and apply this method in statistical learning problems.

Variational analysis

Wed.2.H 2051

Equilibrium problems: Formulations and methodologies

Organizer/Chair Patrizia Daniele, University of Catania · Invited Session

Patrizia Daniele, University of Catania

General financial models: Methodologies and suggestions for the recovery

We present a general time-dependent equilibrium model of financial flows and prices, obtaining the equilibrium conditions and the governing variational inequality formulation. Using delicate tools of Nonlinear Analysis and especially some properties of the dual model (the so called shadow problem), the optimal composition of assets, liabilities and prices is determined and a qualitative analysis of the equilibrium is performed.

Giovanni Crespi, University of Valle d'Aosta (with Andreas Hamel, Carola Schrage)

Minty variational principle in set optimization

In scalar optimization it is well known that a solution of a Minty variational inequality of differential type is a solution of the primitive optimization problem. This relation is known as “Minty variational principle.” In the vector case, the links between Minty variational inequalities and vector optimization problems were deeply investigated in the last decades. In the field of vector optimization some convexity assumptions are needed to state the result. We aim to extend such results to set optimization, using suitable notions of solution to the optimization problem and a new approach to the definition of a differential type variational inequality associated to a set-valued function. To this extent a Dini type derivative for a class set-valued functions will be introduced, convexity and monotonicity will be discussed by means of suitable scalarization techniques. The concepts of infimum in set optimization and non dominated elements will be investigated.

Tina Wakolbinger, WU (Vienna University of Economics and Business) (with Patrizia Daniele, Fuminori Toyasaki)

A variational inequality formulation of economic network equilibrium models with nonlinear constraints

Variational inequality theory facilitates the formulation of equilibrium problems in economic networks. Examples of successful applications include models of supply chains, financial networks, transportation networks, and electricity networks. Previous economic network equilibrium models that were formulated as variational inequalities only included linear constraints. In this paper, we first highlight with an application from the context of reverse logistics why the introduction of nonlinear constraints is beneficial. We then show mathematical conditions that ensure that the models have unique solutions and we suggest algorithms that can be applied to solve the models

Approximation & online algorithms

Wed.3.H 3010

Randomized rounding algorithms in mathematical programming

Organizer/Chair Maxim Sviridenko, University of Warwick · Invited Session

Viswanath Nagarajan, IBM Research (with Anupam Gupta, R. Ravi)

Thresholded covering algorithms for robust and max-min optimization

We consider combinatorial covering problems (eg. Set cover, Steiner forest and Multicut) in the context of “robust” and “max-min” optimization. Given an instance of a covering problem P with n demands and parameter k :

- (I) The k -max-min version of P asks for k (out of n) demands that are the costliest to cover.
- (II) The k -robust version of P is a two-stage optimization problem, where an arbitrary subset D of k demands materializes in the second stage. Elements (that cover demands) are more expensive in the second stage than the first. The objective is to anticipatorily purchase some elements in the first stage, so as to minimize the worst-case covering cost (sum of both stages) over all possible demands D .

We present an algorithmic template that achieves nearly tight approximation guarantees for k -robust and k -max-min versions of many covering problems. The analysis is based on establishing certain net-type properties, that rely on LP dual-rounding and primal-dual arguments.

Barna Saha, AT&T Shannon Research Laboratory (with Bernhard Haeupler, Aravind Srinivasan)

The constructive aspects of the Lovász Local Lemma: finding needles in a haystack

The well-known Lovász Local Lemma (LLL) is a powerful probabilistic approach to prove the existence of certain combinatorial structures. While the original LLL was non-constructive – it was unclear how the existence proofs could be turned into polynomial-time algorithms – a series of works beginning with Beck and culminating with the breakthrough of Moser & Tardos (MT) have led to efficient algorithmic versions for most such proofs. However, there are several LLL applications to which these approaches inherently cannot apply. Our work makes progress toward bridging this gap.

One of our main contribution is to show that when a LLL application provides a small amount of slack, the number of resamplings of the MT algorithm is nearly linear in the number of underlying independent variables (not events!), and can thus be used to give efficient constructions in cases where the underlying proof applies the LLL to super-polynomially many events, and even in cases where finding a bad event that holds is computationally hard. This leads to simple and efficient Monte-Carlo algorithms, in several cases resulting in the first efficient algorithms known.

Aravind Srinivasan, University of Maryland

Dependent rounding and its applications

Randomized rounding is a well-known and powerful tool in rounding solutions to relaxations of optimization problems. Starting with the work of Ageev and Sviridenko, the notion of dependent randomized rounding has led to significant progress in a variety of (approximation) algorithms: one carefully defines dependencies between several basic random variables in the rounding process. We will present a brief survey of this area, including works of the speaker and those of Calinescu, Chekuri, Pal and Vondrak.

Combinatorial optimization

Wed.3.H 3004

Knapsack and bin packing

Chair Alantha Newman, DIMACS

Alantha Newman, DIMACS (with Ofer Neiman, Aleksandar Nikolov)

A counterexample to Beck’s three permutations conjecture

Given three permutations on the integers 1 through n , consider the set system consisting of each interval in each of the three permutations. In 1982, József Beck conjectured that the discrepancy of this set system is $O(1)$. In other words, Beck conjectured that for every three permutations, each integer from 1 through n can be colored either red or blue so that the number of red and blue integers in each interval of each permutation differs only by a constant. (The discrepancy of a set system based on two permutations is two.)

In this talk, we give a counterexample to this conjecture: for any positive integer $n = 3^k$, we construct three permutations whose corresponding set system has discrepancy $\Omega(\log n)$. Our counterexample is based on a simple recursive construction, and our proof of the discrepancy lower bound is by induction.

We also present implications of this construction for the bin packing problem: There are instances of bin packing problem and corresponding basic feasible LP solutions, such that any packing that only uses patterns from the support of these solutions requires at least $OPT + \Omega(\log n)$ bins.

Paolo Detti, University of Siena

The bounded sequential multiple knapsack problem

The Bounded Multiple Knapsack Problem (BMKP) is a generalization of the 0-1 multiple knapsack problem, where a bounded amount of each item type is available. In this work, a special case of BMKP is considered in which the sizes of the items are divisible. This problem is known in the literature as Bounded Sequential Multiple Knapsack Problem (BSMKP). Several authors have addressed the Bounded Sequential Knapsack Problem (BSKP). Pochet and Weismantel provided a description of the bounded sequential single-knapsack polytope. Polynomial time algorithms for BSKP and BSMKP are also proposed in the literature. This work basically extends the study of Pochet and Weismantel to BSMKP. Specifically, problem transformations are proposed for BSMKP that allow a characterization of the optimal solutions and the description

of the BSMKP polytope. Keywords: bounded sequential multiknapsack, optimal solutions, polytope description.

Joachim Schauer, University of Graz (with Ulrich Pferschy)

Knapsack problems with disjunctive constraints

We study the classical 0-1 knapsack problem subject to binary disjunctive constraints. Conflict constraints state that certain pairs of items cannot be simultaneously contained in a feasible solution. Forcing constraints enforce at least one of the items of each given pair to be included into the knapsack. A natural way for representing these constraints is the use of conflict (resp. forcing) graphs. We will derive FPTASs for the knapsack problem with chordal forcing graphs and with forcing graphs of bounded treewidth - complementing results for the conflict graph case given in Pferschy and Schauer (2009). The result for chordal forcing graphs is derived by a transformation of the problem into a minimization knapsack problem with chordal conflict graphs. We will furthermore give a PTAS for the knapsack problem with planar conflict graphs. In contrast the corresponding forcing graph problem is inapproximable. Similar complexity results are given for subclasses of perfect graphs as conflict (resp. forcing) graphs.

Combinatorial optimization

Wed.3.H 3005

Graph coloring

Chair Jakub Marecek, IBM Research

Noriyoshi Sukegawa, Tokyo Institute of Technology (with Yoshitsugu Yamamoto, Liyuan Zhang)

Lagrangian relaxation and pegging test for clique partitioning problems

We develop a relaxation method to solve the clique partitioning problem (CPP), as it is done customarily by the Lagrangian relaxation, but in a new approach we have aimed at overcoming the burden imposed by the number of constraints. Since the binary integer linear programming formulation of CPP has a huge number of inequality constraints, we propose a modified Lagrangian relaxation which discards some of the multipliers and the modified subgradient method to solve the Lagrangian dual problem defined by the modified Lagrangian relaxation. This modification enables us to apply the Lagrangian relaxation to large instances. Computational results show that only a small fraction of all constraints are considered eventually. We also propose an improvement of the ordinary pegging test by using the structural property of CPP. The pegging test reduces the size of given instances, often significantly, and contributes to finding a very tight upper bound for several instances.

Noriyoshi Sukegawa, Tokyo Institute of Technology (with Yoshitsugu Yamamoto, Liyuan Zhang)

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Jakub Marecek, IBM Research (with Andrew Parkes)

Semidefinite programming relaxations in timetabling and matrix-free implementations of augmented Lagrangian methods for solving them

Semidefinite programming provides the best known relaxations of graph colouring solvable in time polynomial in the dimensions of the graph. In order to derive strong bounds for timetabling and scheduling problems extending graph colouring, however, one cannot consider the graph colouring component alone.

We present semidefinite programming relaxations of graph colouring with an upper bound on the number of uses of each colour and numerous extensions encountered in timetabling. In timetabling terms, we consider the number of rooms available, room sizes, room features, room assignment stability, and pre-allocated room assignments.

The relaxations can be solved efficiently using alternating direction augmented Lagrangian methods (ALM). We present an ALM, which exploits the structure of the matrices involved and is essentially "matrix-free" except for a projection on the cone of positive semidefinite matrices. It can be shown the rate of convergence of ALMs within a given error

bound is asymptotically the best possible, among first-order methods. The computational results suggest this may turn out to be the method of choice in practical timetabling.

Combinatorial optimization

Wed.3.H 3008

Competitive and multi-objective facility location

Chair Yury Kochetov, Sobolev Institute of Mathematics

Vladimir Beresnev, Sobolev Institute of Mathematics

Algorithms for discrete competitive facility location problem

We consider a mathematical model generalizing the well-known facility location problem. In this model two rival sides (Leader and Follower) sequentially open their facilities and aim to capture clients in order to make maximal profit. We state the problem as a bilevel integer programming problem. It includes the upper level (Leader's) problem and the lower level (Follower's) problem. We consider so-called optimal noncooperative solutions to the problem, where from all possible optimal solutions to Follower's problem we choose the solution which yields the smallest value of the objective function of the Leader's problem. We represent our problem as the problem of maximizing a pseudo-Boolean function. We propose a local search algorithm for constructing an approximate solution to the problem and a branch-and-bound algorithm for finding an optimal solution of the problem. An important ingredient of the algorithms is a method for calculating an upper bound for the values of the pseudo-Boolean function on subsets of solutions.

Yury Kochetov, Sobolev Institute of Mathematics (with Emilio Carrizosa, Ivan Davydov, Alexandr Plyasunov)

A local search algorithm for the $(r | p)$ -centroid problem on the plane

In the $(r | p)$ -centroid problem two players, leader and follower, open facilities to service clients. We assume that clients are on the Euclidean plane and facilities can be opened in arbitrary points on the plane. Leader opens p facilities. Later on, follower opens r facilities. Each client patronizes the closest facility. Our goal is to find p facilities for the leader to maximize his market share. We show that the problem is Σ_2^P -hard. In other words, this Stackelberg game is more difficult than well-known NP-complete problems, unless $P=NP$. To find near optimal solutions we develop a local search heuristic, based on the exact approach for the follower problem. We apply discretization of the $(r | \lambda_{p-1} + 1)$ -centroid problem where the leader can move one facility only in order to identify the best neighboring solution. Starting solution is generated by a new alternating heuristic and an exact polynomial time algorithm for the $(1 | 1)$ -centroid problem. Computational experiments for the randomly generated test instances show that this local search algorithm dominates the previous heuristics.

Marta Pascoal, INESC-Coimbra and University of Coimbra (with Gilbert Laporte)

Path based method for multicriteria metro location

We model the metro location problem considering the maximization of the population covered by the metro stations, the minimization of the construction cost and the minimization of the metro line lengths, under some constraints. Sets of efficient metro lines and correspondent metro stations are obtained by applying a path based algorithm. The metro lines are then combined following traditional metro configurations by means of solving a multicriteria linear program.

Combinatorial optimization

Wed.3.H 3012

Heuristics III

Chair Beyzanur Cayir, Anadolu University

Polina Kononova, Novosibirsk State University (with Yury Kochetov)

Local search heuristic for the buffer-constrained two-stage multimedia scheduling problem

We consider a two-machine flowshop scheduling problem originating in the multimedia industry. It is known that the problem is strongly NP-hard. We present some ILP-reformulations to get lower bounds and VNS-metaheuristic to find optimal or near optimal solutions. The Kernighan-Lin neighborhoods and job-window neighborhoods are used in the VNS framework. For experiments we generate large scale instances with known global optima. Computational results and some open questions are discussed.

Beyzanur Cayir, Anadolu University (with Nil Aras)

A genetic algorithm for truck to door assignment in warehouses

Customer satisfaction is crucial for companies to survive. Right shipment planning is indispensable process of warehouse management

in supply chain and logistics management. This problem is similar to the problem of gate assignments in airports. We consider the over-constrained truck-to-door assignment problem with time window, operational time and customer priority constraints in warehouse where the number of vehicles exceed the number of doors available. The problem feasibility is affected by three factors: the arrival and departure time window of each type of vehicle, loading time for orders, total distance to customers. Objective of this study is to minimize total lead time and deviations from expected delivery time. Otherwise a penalty cost occurs for late or early delivery. Penalty cost depends on customer priorities. In this study, formulation of a mixed integer model for optimal solution of the vehicle scheduling problem is described and a genetic algorithm is proposed which can search for practical optimal solutions, on the basis of the theory of natural selection, without performing all searches. The computational experiment is carried out on real life instances.

Combinatorial optimization

Wed.3.H 3013

Polyhedra in combinatorial optimization

Chair Shungo Koichi, Nanzan University

Shungo Koichi, Nanzan University

A note on ternary semimodular polyhedra

A ternary semimodular polyhedron associated with a submodular function on $\{0, \pm 1\}$ vectors was introduced by Fujishige in 1984, and it is not necessary integral even if the submodular function is integer-valued. However, it is known that the polyhedron has a nice property that corresponds to a laminarity property of the (standard) submodular polyhedra. In this paper, we give a slightly different type of polyhedron associated with a submodular function on $\{0, \pm 1\}$ vectors, and show that it also has the nice property as above and moreover, due to the nice property, it is quarter-integral if the submodular function is integer-valued. In addition, this paper proposes a variant of a submodular function on $\{0, \pm 1\}$ that preserves the quarter-integrality of the newly-defined associated polyhedron. The proof uses the result by Karzanov in 2007 concerning the integrality of the intersection of two integer bisubmodular polyhedra. Our results may be applicable to the multicommodity flow problem, which is our motivation.

Aleksandr Maksimenko, Yaroslavl State University

The common face of some 0/1 polytopes with NP-complete nonadjacency relations

We consider so-called double covering polytopes (DCP). In 1995, Matsui showed that the problem of checking nonadjacency on these polytopes is NP-complete. We show that double covering polytopes are faces of the following polytopes: knapsack polytopes, set covering polytopes, cubic graph polytopes, 3-SAT polytopes, partial order polytopes, traveling salesman polytopes, and some others. Thus, these families of polytopes inherit the property of NP-completeness of nonadjacency relations from DCP. We show also that the graph of a double covering polytope has superpolynomial clique number. The same is true for the mentioned families of polytopes.

Shanfei Li, Delft University of Technology (with Karen Aardal)

The polyhedral relationship between the capacitated facility location polytope and its knapsack and single-node flow relaxations

The knapsack and single node flow polytopes, X_K and X_{SNF} respectively, are well-known relaxations of the capacitated facility location polytope X_{CFL} . In earlier studies specific classes of facets for X_K and X_{SNF} have been proved to be facets also for X_{CFL} , and the computational effectiveness of these classes have also been demonstrated for X_{CFL} . In this presentation we prove more general relationships between the polytopes X_K , X_{SNF} , and X_{CFL} . We also prove results in the spirit of Goemans' worst-case comparison of valid inequalities.

Combinatorial optimization

Wed.3.H 3021

Routing in road networks

Organizer/Chair Andrew Goldberg, Microsoft Research · Invited Session

Peter Sanders, Karlsruhe Institute of Technology (with Veit Batz, Robert Geisberger, Moritz Kobitzsch, Dennis Luxen, Dennis Schieferdecker)

Advance route planning using contraction hierarchies

Contraction hierarchies are a simple and powerful way to grasp the hierarchical structure of road networks allowing very fast routing. The talk introduces the technique and gives applications focussing on advanced techniques like taking time-dependent travel times into account

or using multiple objective functions. We also discuss applications like fast distance table precomputation for logistics or ride sharing.

Andrew Goldberg, Microsoft Research (with Ittai Abraham, Daniel Delling, Amos Fiat, and Renato Werneck)

The hub labeling algorithm

The labeling approach to distance oracle design is to precompute a label for every vertex so that distances can be computed from the corresponding labels. This approach has been introduced by [Gavoille et al. '01], who also introduced the Hub Labeling algorithm (HL). HL has been further studied by [Cohen et al. '02].

We study HL in the context of graphs with small highway dimension (e.g., road networks). We show that under this assumption HL labels are small and the queries are sublinear. We also give an approximation algorithm for computing small HL labels that uses the fact that shortest path set systems have small VC-dimension.

Although polynomial-time, precomputation given by theory is too slow for continental-size road networks. However, heuristics guided by the theory are fast, and compute very small labels. This leads to the fastest currently known practical distance oracles for road networks. HL also has efficient (real-time) implementation inside of a relational database (e.g., in SQL).

Daniel Delling, Microsoft Research Silicon Valley (with Andrew Goldberg, Thomas Pajor, Ilya Razenshteyn, Renato Werneck)

Realistic route planning in road networks

I will present an extremely practical algorithm to compute shortest paths on continental road networks with arbitrary metrics (cost functions). The approach has very low space usage per metric, supports real-time queries, and can incorporate a new metric in a few seconds. As a result, it can easily handle real-time traffic updates and personalized optimization functions. Unlike most previous methods, ours does not rely on the strong hierarchy observed on road networks with travel times as the cost function, making it much more robust to metric changes. Our algorithm uses the fact that road networks can be partitioned into loosely connected regions. To find such partitions, we developed a new algorithm based on the notion of natural cuts, which are sparse regions separating much denser areas.

This approach is currently used by Bing Maps.

Complementarity & variational inequalities

Wed.3.MA 313

Applications of complementarity

Chair Wen Chen, The University of Western Australia

Jong-Shi Pang, University of Illinois at Urbana-Champaign (with Dane Schiro)

On differential linear-quadratic Nash games with mixed state-control constraints

This paper addresses the class of open-loop differential linear-quadratic Nash games with mixed state-control constraints. A sufficient condition is provided under which such a game is equivalent to a certain concatenated linear-quadratic optimal control problem. This equivalent formulation facilitates the application of a time-stepping algorithm whose convergence to a continuous-time Nash equilibrium trajectory of the game can be established under certain conditions. Another instance of this game is also analyzed for which a convergent distributed algorithm can be applied to compute a continuous-time equilibrium solution.

Vadim Shmyrev, Sobolev Institute of Mathematics

A polyhedral complementarity algorithm for searching an equilibrium in the linear production-exchange model.

A finite algorithm for searching an equilibrium in a linear production-exchange model will be presented. The algorithm is based on the consideration of two dual polyhedral complexes associating with the model. The intersection point of two corresponding each other polyhedrons of the complexes yields equilibrium prices. Thus, we deal with polyhedral complementarity. The mentioned approach made it possible to propose also finite algorithms for some other modifications of the exchange model. These algorithms can be considered as analogues of the simplex method of linear programming.

Wen Chen, The University of Western Australia (with Song Wang)

A power penalty method for fractional Black-Scholes equations governing American option pricing

In this talk, we present a power penalty approach to the linear fractional differential complementarity problem arising from pricing American options under a geometric Levy process. The problem is first reformulated as a variational inequality, and the variational inequality is then approximated by a nonlinear fractional partial differential equation (fPDE) containing a power penalty term. We will show that the solution

to the penalty fPDE converges to that of the variational inequality problem with an exponential order. A finite difference method is proposed for solving the penalty nonlinear fPDE. Numerical results will be presented to illustrate the theoretical findings and to show the effectiveness and usefulness of the methods.

Conic programming

Wed.3.H 2036

First-derivative methods in convex optimization

Organizer/Chair Stephen Vavasis, University of Waterloo · Invited Session

Yoel Drori, Tel Aviv University (with Marc Teboulle)

Performance of first-order methods for smooth convex minimization: A novel approach

We introduce a novel approach for analyzing the performance of first-order black-box optimization methods. Following the seminal work of Nemirovski and Yudin (1983) in the complexity analysis of convex optimization methods, we measure the computational cost based on the oracle model of optimization. Building on this model, our approach relies on the observation that by definition, the worst case behavior of a black-box optimization method is by itself an optimization problem, which we call the Performance Estimation Problem (PEP). We analyze the properties of the resulting PEP for various black-box first order schemes. This allows us to prove a new tight analytical bound for the classical gradient method, as well as to derive numerical bounds that can be efficiently computed for a broad class of first order schemes. Moreover, we derive an efficient procedure for finding step sizes which produces a first-order black-box method that achieves best performance.

Clovis Gonzaga, Federal University of Santa Catarina – Brazil

On the complexity of steepest descent algorithms for minimizing quadratic functions

We discuss the question of how fast a steepest descent algorithm can be for minimizing a convex quadratic function. We do not tackle the general case of convex differentiable functions, which is more difficult. Steepest descent methods differ exclusively on the choice of step length at each iteration. We examine patterns in the distribution of these step lengths for minimizing a convex quadratic function. We show how a large number of short steps are needed, and how these relate to the much smaller number of large steps. We note that the order in which the step lengths are used is irrelevant, and show a worst case example with a small number of variables. We also conceive a brute force algorithm which is in a certain way optimal, and compare it with known algorithms.

Sahar Karimi, University of Waterloo (with Stephen Vavasis)

CGSO for convex problems with polyhedral constraints

We have proposed CGSO (Conjugate Gradient with Subspace Optimization) as an extension to Nemirovski-Yudin's algorithm. CGSO is a conjugate gradient type algorithm that benefits from the optimal complexity bound Nemirovski-Yudin's algorithm achieves for the class of unconstrained convex problems. In this talk, we discuss CGSO for convex problems with polyhedral constraints. We study the theoretical properties as well as the practical performance of CGSO for this class of problems.

Conic programming

Wed.3.H 2038

Conic and convex programming in statistics and signal processing IV

Organizer/Chair Parikshit Shah, University of Wisconsin · Invited Session

Defeng Sun, National University of Singapore (with Weimin Miao)

Finding the nearest correlation matrix of exact low rank via convex optimization

In this talk, we aim to find a nearest correlation matrix of exact low rank from n independent noisy observations of entries under a general sampling scheme. Since the nuclear norm (trace) of a correlation matrix is a constant, the widely used nuclear norm regularization technique can no longer be applied to achieve this goal in the noisy setting. Here, we propose a new convex optimization approach by using a linear regularization term based on the observation matrix to represent the rank information. This convex optimization problem can be easily written as an H -weighted least squares semidefinite programming problem, which can be efficiently solved, even for large-scale cases. Under certain conditions, we show that our approach possesses the rank consistency. We also provide non-asymptotic bounds on the estimation error.

Sahand Negahban, MIT (with Alekh Agarwal, Martin Wainwright)

Fast global convergence of composite gradient methods for high-dimensional statistical recovery

Many statistical M -estimators are based on convex optimization

problems formed by the combination of a data-dependent loss function with a norm-based regularizer. We analyze the convergence rates of composite gradient methods for solving such problems, working within a high-dimensional framework that allows the data dimension d to grow with (and possibly exceed) the sample size n . This high-dimensional structure precludes the usual global assumptions—namely, strong convexity and smoothness conditions—that underlie much of classical optimization analysis. We define appropriately restricted versions of these conditions, and show that they are satisfied with high probability for various statistical models. Under these conditions, our theory guarantees that composite gradient descent has a globally geometric rate of convergence up to the statistical precision of the model, meaning the typical distance between the true unknown parameter θ^* and an optimal solution $\hat{\theta}$. This result is substantially sharper than previous convergence guarantees. These results extend existing ones based on constrained M -estimators.

Maryam Fazel, University of Washington (with Ting Kei Pong, Defeng Sun, Paul Tseng)

Algorithms for Hankel matrix rank minimization for system identification and realization

We introduce a flexible optimization framework for nuclear norm minimization of matrices with linear structure, including Hankel, Toeplitz and Moment structures, and catalog applications from diverse fields under this framework. We discuss first-order methods for solving the resulting optimization problem, including alternating direction methods, proximal point algorithm and gradient projection methods. We perform computational experiments comparing these methods on system identification and system realization problems. For the system identification problem, the gradient projection method (accelerated by Nesterov's extrapolation techniques) outperforms other first-order methods in terms of CPU time on both real and simulated data; while for the system realization problem, the alternating direction method, as applied to a certain primal reformulation, outperforms other first-order methods.

Constraint programming

Wed.3.H 3003A

Computational sustainability

Organizer/Chair Alan Holland, University College Cork · Invited Session

Alan Holland, University College Cork (with Barry O'sullivan)

Optimising the economic efficiency of monetary incentives for renewable energy investment

Many governments have instituted policies to support the increased generation of electricity using renewable energy devices, and there is compelling need to ensure that publicly funded subsidy schemes are operated in a manner that maximizes societal benefit. We consider the mechanism design problem associated with the rollout of an auction for monetary incentives to support the increased deployment of renewable energy devices. We assume a game-theoretic model with self-interested agents that behave strategically in order to maximize their expected utility. We seek to develop algorithms for the assignment of investment subsidies and determination of payoff that are resilient to the possibility that agents will lie in order to manipulate the outcome for their own benefit. We seek to minimize the maximum cost imposed on any single agent thus ensuring that a wide distribution of subsidies can be expected. This problem is analogous to solving a makespan minimization problem and has associated algorithmic design challenges when we require a mechanism that can support the elicitation of preferences from potentially tens of thousands of agents in public auctions.

Rene Schönfelder, University of Lübeck (with Martin Leucker)

Stochastic routing for electric vehicles

The development of electric vehicles (EV) using regenerative energy sources introduces various new algorithmic challenges. One aspect is to find efficient driving directions in order to consume less energy in general and to account for special properties of EVs in particular. Besides the length of the route, one could take various parameters into account, such as altitude maps, congestion probabilities, the weather forecast, multi-modality, the energy consumption of a fleet or of the overall traffic. We present some models to account for stochastic elements, such as congestion, traffic lights or similar uncertainties. Two particular models will be used to optimize either the success probability (i.e. the chance to reach your destination with the current battery charge) or the conditional expectation value of the energy use (given that a minimal success rate is satisfied). By adapting an algorithm from Uludag et al., we developed an algorithm to approach the mentioned energy-optimal path

problems. Furthermore we provide a unified routing model to account for time-dependency and energy-constraints as well as stochasticity.

Marco Gavanelli, University of Ferrara (with Michela Milano, Fabrizio Riguzzi)

Simulation and optimization for sustainable policy-making

Policy-making for European regions is becoming more and more challenging. Good policies should take into account environmental sustainability, economic factors and social acceptance of the policy. Optimization promises to improve currently adopted, hand-made solutions and may mean large savings for the taxpayers and lower depletion of limited resources, given the scale of regional planning. On the other hand, the effectiveness of a policy depends strongly on the response of the population, which cannot be easily foreseen. In fact, it is the emerging behavior of a complex system, for which one can, at most, exploit a simulator. From this, one wishes to extract mathematical relationships to be modeled as constraints. In order to extract significant information from simulations, they should be run a statistically significant number of times, and the results aggregated through statistical analysis or machine learning. We show how optimization has been applied in the regional energy plan of the Emilia-Romagna region, in Italy. We propose an approach for the combination of simulation and combinatorial optimization that we evaluate experimentally.

Derivative-free & simulation-based opt.

Wed.3.H 3503

Stochastic zero-order methods

Organizers/Chairs Stefan Wild, Argonne National Laboratory; Luis Nunes Vicente, University of Coimbra · Invited Session

Joao Lauro Faco, Federal University of Rio de Janeiro (with Mauricio Resende, Ricardo Silva)

A continuous GRASP for global optimization with general linear constraints

A new variant of the global optimization method Continuous GRASP (C-GRASP) is presented. The new variant incorporates general linear constraints in addition to box constraints. C-GRASP solves continuous global optimization problems subject to box constraints by adapting the greedy randomized adaptive search procedure (GRASP) of Feo and Resende (1989) for discrete optimization. It has been applied to a wide range of continuous optimization problems. We consider the box constraints as implicit and handle the general linear equality/inequality constraints explicitly. If we are given an $m \times n$ matrix A , with $m < n$, then m basic variables can be eliminated from the global optimization problem. A Reduced Problem in $(n - m)$ independent variables will be subject only to the box constraints. The C-GRASP solver is a derivative-free global optimization method yielding an optimal or near-optimal solution to the Reduced Problem. The basic variables can be computed by solving a system of linear equations. If all basic variables are inside the box, the algorithm stops. Otherwise a change-of-basis procedure is applied, and a new Reduced Problem is solved.

Sebastian Stich, ETH Zürich (with Bernd Gärtner, Christian Müller)

Convergence of local search

We study unconstrained optimization of convex functions. Many algorithms generate a sequence of improving approximate solutions to this optimization problem. Usually, these algorithms are analyzed by estimating the (expected) one-step progress. However, in case of randomized algorithms it is often difficult to obtain bounds on the variance of the whole process. We present a general framework to analyze local search algorithms. Suppose that an algorithm proposes in each iteration exactly one new feasible solution that sufficiently improves the last iterate, i.e. a local decrease condition is satisfied. Karmanov (1974) presented a genuine method to analyze such a local search algorithm for differentiable convex functions. We extend his approach to strongly convex functions where linear convergence rates can be established with high probability. This approach can be used to analyze deterministic as well as randomized optimization algorithms. We show that for instance the Random Gradient method (Nesterov 2011), as well as Random Pursuit (Stich et al. 2011) can be analyzed by this framework. We conclude with another interesting example, namely derivative-free local metric learning.

Anne Auger, INRIA Scalay-Ile-de-France (with Youhei Akimoto, Nikolaus Hansen)

Convergence of adaptive evolution strategies on monotonic C^2 -composite and scale-invariant functions

Evolution Strategies (ES) are stochastic search algorithms for numerical black-box optimization where a family of probability distributions is iteratively adapted to ultimately converge to a distribution concentrated on optima of the function. They are derivative-free methods using the objective function through the ranking of candidate solutions. Hence they are invariant when optimizing f or $g \circ f$ where $g : \mathbb{R} \rightarrow \mathbb{R}$ is monotonically increasing. Recently, some adaptive ESs were shown

to be stochastic approximations of a natural gradient algorithm in the manifold defined by the family of probability distributions. An ODE is naturally associated to this natural gradient algorithm when the step-size goes to zero. Solutions of this ODE are continuous time models of the underlying algorithms.

In this talk we will present convergence results of the solutions of this ODE and prove their local convergence on monotonic C^2 -composite functions towards local optima of the function. We will also present global convergence of the corresponding algorithm on some scale-invariant functions defined as functions such that $f(x) < f(y)$ iff $f(sx) < f(sy)$ for all $s > 0$.

Finance & economics

Wed.3.H 3027

Management of portfolios and liabilities

Organizers/Chairs Dan Iancu, Stanford University; Nikos Trichakis, Harvard Business School · Invited Session

Alberto Martín-Utrera, University Carlos III of Madrid (with Victor Demiguel, Francisco Nogales)

Size matters: Calibrating shrinkage estimators for portfolio optimization

We provide a comprehensive study of shrinkage estimators for portfolio selection. We study both portfolios computed from shrinkage estimators of the mean and the inverse covariance matrix, as well as shrinkage portfolios obtained by shrinking the portfolio weights directly. We propose two calibration approaches to determine the shrinkage intensity: a parametric approach based on the assumption that returns are independent and identically distributed as a normal (that leads to closed-form expressions for the shrinkage intensity), and a nonparametric approach that makes no assumptions on the return distribution. We carry out extensive empirical tests across six real datasets.

Nikos Trichakis, Harvard Business School (with Dan Iancu)

Fairness in multi-portfolio optimization

We deal with the problem faced by a portfolio manager in charge of multiple accounts. In such a setting, the performance of each individual account typically depends on the trading strategy of other accounts as well, due to market impact cost of the aggregate trading activity. We propose a novel, tractable approach for jointly optimizing the trading activities of all accounts and also splitting the associated market impact costs between the accounts. Our approach allows the manager to balance the conflicting objectives of maximizing the aggregate gains from joint optimization and distributing them across the accounts in an equitable way. We perform numerical studies that suggest that our approach outperforms existing methods employed in the industry or discussed in the literature.

Pedro Júdice, Montepio Geral and ISCTE Business School (with Birge John, Júdice Pedro)

Long-term bank balance sheet management: Estimation and simulation of risk-factors

We propose a dynamic framework which encompasses the main risks in balance sheets of banks in an integrated fashion. Our contributions are fourfold: 1) solving a simple one-period model that describes the optimal bank policy under credit risk; 2) estimating the long-term stochastic processes underlying the risk factors in the balance sheet, taking into account the credit and interest rate cycles; 3) simulating several scenarios for interest rates and charge-offs; and 4) describing the equations that govern the evolution of the balance sheet in the long run. The models that we use address momentum and the interaction between different rates. Our results enable simulation of bank balance sheets over time given a bank's lending strategy and provides a basis for an optimization model to determine bank asset-liability management strategy endogenously.

Game theory

Wed.3.MA 005

Network sharing and congestion

Organizer/Chair Laurent Gourves, CNRS · Invited Session

Alexandre Blogowski, Orange Labs - LIP 6 (with Ouorou Adam, Pascual Fanny, Bouhtou Mustapha, Chrétienne Philippe)

Access network sharing between two telecommunication operators

We study the sharing of an existing radio access network (set of base stations antennas) between two telecommunication operators. For each base station, an operator has to decide whether it covers it, in which case it gains a profit, or not. This profit may be different if it is alone to cover the base station, or if both operators cover the base station (by

covering a same base station, both operators decrease their costs, but they may also cover less clients). We model this situation by a game, where each agent is an operator and the strategy set of each agent is the set of base stations it covers. We study the existence of Nash equilibria, the price of anarchy and the price of stability for various settings. We also study how the agents may cooperate so that both obtain larger profits than in a Nash equilibrium. Finally, we conduct experiments to measure the gain obtained.

Cheng Wan, Université Pierre et Marie Curie - Paris 6, Institut de Mathématiques de Jussieu

Coalitions in nonatomic network congestion games

The work studies coalitions in nonatomic network congestion games. Suppose that a finite number of coalitions are formed by nonatomic individuals. Having established the existence and the uniqueness of equilibrium both in the nonatomic game without coalitions and in the composite game with coalitions and independent individuals, we show that the presence of coalitions benefits everyone: at the equilibrium of the composite game, the individual payoff as well as the average payoff of each coalition exceeds the equilibrium payoff in the nonatomic game. The individual payoff is higher than the average payoff of any coalition. The average payoff of a smaller coalition is higher than that of a larger one. In the case of unique coalition, both the average payoff of the coalition and the individual payoff increase with the size of the coalition. Asymptotic behaviors are studied for a sequence of composite games where some coalitions are fixed and the maximum size of the remaining coalitions tends to zero. It is shown that the sequence of equilibrium of these games converges to the equilibrium of a composite game played by those fixed coalitions and the remaining individuals.

Xavier Zeitoun, LRI

The complexity of approximate Nash equilibrium in congestion games with negative delays

We extend the study of the complexity of computing an ϵ -approximate Nash equilibrium in symmetric congestion games from the case of positive delay functions to delays of arbitrary sign. Our results show that with this extension the complexity has a richer structure, and it depends on the exact nature of the signs allowed. We first prove that in symmetric games with increasing delay functions and with α -bounded jump the ϵ -Nash dynamic converges in polynomial time when all delays are negative, similarly to the case of positive delays. We are able to extend this result to monotone delay functions. We then establish a hardness result for symmetric games with increasing delay functions and with α -bounded jump when the delays can be both positive and negative: in that case computing an ϵ -Nash equilibrium becomes *PLS*-complete, even if each delay function is of constant sign or of constant absolute value.

Game theory

Wed.3.MA 043

Solving cooperative games

Chair Kazutoshi Ando, Shizuoka University

Tri-Dung Nguyen, University of Southampton

Finding solutions of large cooperative games

The nucleolus is one of the most important solution concepts in cooperative game theory as a result of its attractive properties - it always exists, is unique, and is always in the core (if the core is non-empty). However, computing the nucleolus is very challenging because this involves lexicographical minimization of an exponentially large number of excess values. We present a method for computing the nucleolus of large games. We formulate the problem as nested LPs and solve them using a constraint generation algorithm. Although the nested LPs formulation has been documented in the literature, it has not been used for large games because of the large LPs involved. In addition, subtle issues such as how to deal with multiple optimal solutions and with large tight constraint sets have not been discussed in the literature. These issues are crucial and need to be resolved in each LP in order to formulate and solve the subsequent ones. We treat them rigorously and show that the nucleolus can be found efficiently as long as the worst coalition can be identified for a given imputation. We demonstrate our methodology with the case of the weighted voting games with up to 100 players.

Ping Zhao, City University of Hong Kong (with Chuangyin Dang)

A mixed-integer programming approach to the determination of a core element for an n -person cooperative game with nontransferable utility

A fundamental issue concerning n -person cooperative game with nontransferable utility is about core existence. Sufficient conditions like balancedness and necessary conditions for nonemptiness of the core have been given. From a complexity theoretic standpoint, the core existence problem has been proved to be NP-complete, which also indicates computation of core element intractable in general case. We transform

a core computation problem into a mixed-integer programming problem such that core existence is equivalent to having an integer point in a polytope. The core of a game can be computed directly by this MIP in virtue of approximating characteristic function by a finite numbers of corners. This approach renders sufficient and necessary conditions dispensable and the information about core can be derived directly by solving the mixed-integer programming. Case in large scale can be computed in the MIP through CPLEX.

Kazutoshi Ando, Shizuoka University

Computation of the Shapley value of minimum cost spanning tree games: #P-hardness and polynomial cases

We show that computing the Shapley value of minimum cost spanning tree games is #P-hard even if the cost functions of underlying networks are restricted to be $\{0, 1\}$ -valued. The proof is by a reduction from counting the number of minimum 2-terminal vertex cuts of an undirected graph, which is #P-complete. We also investigate minimum cost spanning tree games whose Shapley values can be computed in polynomial time. We show that if the cost function of the given network is a subtree distance, which is a generalization of a tree metric, then the Shapley value of the associated minimum cost spanning tree game can be computed in $O(n^4)$ time, where n is the number of players.

Global optimization

Wed.3.H 2053

Nonconvex optimization: Theory and algorithms

Organizer/Chair Evrim Dalkiran, Wayne State University - Invited Session

Evrim Dalkiran, Wayne State University (with Hanif Serali)

RLT-POS: Reformulation-linearization technique-based optimization software for polynomial programming problems

We introduce a Reformulation-Linearization Technique (RLT)-based open-source optimization software for solving polynomial programming problems (RLT-POS). We present algorithms and mechanisms that form the backbone of RLT-POS, including grid-bound-factor constraints and semidefinite cuts, constraint filtering techniques, reduced RLT representations, and bound tightening procedures. When implemented individually, each model enhancement has been shown to significantly improve the performance of the standard RLT procedure. When implemented simultaneously, the coordination between model enhancement techniques becomes critical for an improved performance since special structures in the original formulation may be thus affected. More specifically, we discuss the coordination between (a) bound-grid-factor constraints and semidefinite cuts and (b) constraint filtering techniques and reduced RLT representations. We present computational results using instances from the literature as well as randomly generated problems to demonstrate the improvement over a standard RLT procedure, and we compare the performances of the software packages BARON, SparsePOP, and Couenne with RLT-POS.

Hong Ryou, Korea University (with Kedong Yan)

0-1 multilinear programming & LAD patterns

In this paper, we present a new framework for generating LAD patterns based on 0-1 multilinear programming. The new framework is useful in that one can apply standard linearization techniques and obtain all optimization/MILP-based pattern generation models that have been developed in the literature. We demonstrate this and then apply the McCormick's relaxation and logical implications to develop new pattern generation models that involve a small number of 0-1 decision variables and constraints. With experiments on benchmark machine learning datasets, we demonstrate the efficiency of the new MILP models over previously developed ones.

Spencer Schaber, Massachusetts Institute of Technology (with Paul Barton)

Convergence order of relaxations for global optimization of nonlinear dynamic systems

Deterministic methods for global optimization of nonlinear dynamic systems rely upon underestimating problems for rigorous bounds on the objective function on subsets of the search space. Convergence order of numerical methods is frequently highly indicative of their computational requirements, but has not yet been analyzed for these methods. We analyzed the convergence order of the underestimating problems to the original nonconvex problem for one method of nonlinear global dynamic optimization. We found that the convergence order of the underestimating problem is bounded below by the smallest of the convergence orders of the methods used to compute (i) the bounds for the states as well the convex/concave relaxations of the (ii) vector field, (iii) initial condition, and (iv) objective function in terms of the state variables. We compared the theoretical convergence order result to empirical results for several optimal-control and parameter-estimation problems and found that the bounds were valid for all problems and sharp for

some. We confirmed that empirical convergence order is highly correlated with the CPU time for full global dynamic optimization.

Implementations & software

Wed.3.H 0110

Commercial mathematical programming solvers I

Organizer/Chair Hans Mittelmann, Arizona State University · Invited Session

Thorsten Koch, ZIB (with Gerald Gamrath, Hans Mittelmann)

Any progress one year after MIPLIB 2010 ?

It has been a little more than one year after the release of MIPLIB 2010. How much progress has there been in solving these instances and how does this translate into real progress in the ability to solve mixed integer programs.

Michael Perregaard, FICO

Recent advances in the Xpress MIP solver

We will present some of the recent developments in the Xpress MIP solver, with particular emphasis on heuristics. Modellers continually push the boundaries on the size of problems that can be solved and is often satisfied with a solution that is "good enough". This talk will focus on the developments in Xpress to address such problems.

Tobias Achterberg, IBM

Cover probing for mixed integer programs

This talk is about an extension of the probing procedure on binary variables to set covering constraints. We will explain an algorithm to do this efficiently. Computational results based on CPLEX 12.4 assess the impact of the procedure in practice.

Implementations & software

Wed.3.H 1058

Software for large-scale optimization

Organizer/Chair Denis Ridzal, Sandia National Labs · Invited Session

Kevin Long, Texas Tech University (with Paul Boggs, Bart van Bloemen Waanders)

Sundance: High-level software for PDE-constrained optimization

Sundance is a package in the Trilinos suite designed to provide high-level components for the development of high-performance PDE simulators with built-in capabilities for PDE-constrained optimization. We review the implications of PDE-constrained optimization on simulator design requirements, then survey the architecture of the Sundance problem specification components. These components allow immediate extension of a forward simulator for use in an optimization context. We show examples of the use of these components to develop full-space and reduced-space codes for linear and nonlinear PDE-constrained inverse problems.

Stefan Richter, ETH Zurich (with Jones Jones, Manfred Morari, Fabian Ullmann)

FiOrdOs: A Matlab toolbox for C-code generation for first-order methods

FiOrdOs is the first toolbox for automated C-code generation for first-order methods. It considers the class of multi-parametric convex programs with a quadratic cost and a feasible set given as the intersection of an affine set and a "simple" convex set for which a projection can be evaluated at low cost; this class comprises important embedded optimization problems, for example, model predictive control. The toolbox implements both polyhedral and non-polyhedral simple sets, e.g. the simplex and 1-norm ball and the 2-norm ball and second-order cone respectively. Thus, solver code for problems beyond quadratic programming can be generated. If required, the solution approach is based on Lagrange relaxation which uses the gradient or the fast gradient method at a lower level. Additional toolbox features include optimal preconditioning and the automatic certification of the iteration count for a restricted set of problems. The generated C-code can be compiled for any platform and can be made library-free. FiOrdOs also provides a tailored MEX-interface for calling the generated solvers inside Matlab and a Simulink library for rapid prototyping.

Eric Phipps, Sandia National Laboratories (with Roger Pawlowski, Andy Salinger)

Support embedded algorithms through template-based generic programming

We describe a framework for incorporating embedded analysis algorithms, such as derivative-based optimization and uncertainty quantification, in large-scale simulation codes using template-based generic programming. The framework is based on standard C++ language constructs such as templating, operator overloading, expression templates, and template metaprogramming, and enables the incorporation

of advanced algorithms with a minimum of programmer effort. In this talk we describe the overall approach, several software tools implementing the approach in the Trilinos solver framework, and examples demonstrating the usefulness of the approach applied to optimization and uncertainty quantification of large-scale PDE-based simulations.

Integer & mixed-integer programming

Wed.3.H 2032

Scheduling III

Chair Rüdiger Stephan, TU Berlin / Zuse Institute Berlin

Nelson Hein, Universidade Regional de Blumenau (FURB) (with Adriana Kroenke, Volmir Wilhelm)

Mathematical model of hierarchical production planning

The use of hierarchical model is mostly related to some of the advantages it may provide this type of planning, like a lower requirement for higher level of detailed information, a more simplified formulation of the global model and the gradual introduction of the random effects. Furthermore, beside the advantage of reducing the computational resources, this approach allows a better establishment of parallelism between his formulation and the hierarchy of decisions in the organization. Hierarchical models have been widely used to represent the processes of planning operations in companies. So far, the practical implementation of these models has been made under a, somewhat, formal approach. In this case, a hierarchical model is presented, which takes into consideration a great deal of the complexity that is commonly brought up in production environments. A methodology based on goal programming (applied to different disaggregation procedures to make room for the hierarchical planning) is utilized to solve this matter. This study aims at presenting a proposed methodology, the results obtained when applying it in a practical case, and the conclusions that derive from it.

Diego Recalde, Escuela Politécnica Nacional (with Ramiro Torres, Polo Vaca)

Scheduling the Ecuadorian professional football league by integer programming

A sports schedule fixes the dates and venues of games between teams in a sports league. Constructing a sports schedule is a highly restrictive problem. The schedule must meet constraints due to regulations of a particular sports league Federation and it must guarantee the participation of all teams on equal terms. Moreover, economic benefits of teams, and other agents involved in this activity are expected. Until 2011, the Ecuadorian Football Federation (FEF) has developed schedules for their professional football championship manually. In early 2011, the authors presented to the FEF authorities several evidences that the use of mathematical programming to elaborate feasible sports schedules could easily exceed the benefits obtained by the empirical method. Under the last premises, this work presents an Integer Programming formulation for scheduling the professional football league in Ecuador, which is solved to optimality, and also a three phase decomposition approach for its solution. The schedules obtained fulfilled the expectations of the FEF and one of them was adopted as the official schedule for the 2012 edition of the Ecuadorian Professional Football Championship.

Rüdiger Stephan, TU Berlin / Zuse Institute Berlin

Smaller compact formulation for lot-sizing with constant batches

We consider a variant of the classical lot-sizing problem in which the capacity in each period is an integer multiple of some basic batch size. Pochet and Wolsey (MathOR 18, 1993) presented an $O(n^2 \min\{n, C\})$ algorithm to solve this problem and a linear program with $O(n^3)$ variables and inequalities, where n is the number of periods and C the batch size. We provide a linear program of size $O(n^2 \min\{n, C\})$, that is, in case that $C < n$, our formulation is smaller.

Integer & mixed-integer programming

Wed.3.H 2032

Branch-and-price I: Generic solvers

Organizer/Chair Marco Lübbecke, RWTH Aachen University · Invited Session

Marco Lübbecke, RWTH Aachen University (with Martin Bergner, Gerald Gamrath, Christian Puchert)

A generic branch-price-and-cut solver

We implemented GCG, a branch-price-and-cut solver based on the branch-price-and-cut framework SCIP. Given a MIP, the solver performs a Dantzig-Wolfe reformulation (based on user input, or in some cases the solver suggests a reformulation), does column generation and full branch-price-and-cut. GCG inherits advanced MIP solving features from SCIP, like presolving, propagation, [combinatorial] cutting planes, pseudo-costs etc. A number of additional plugins are implemented which are specific to exploiting the availability of having an original compact and an extended column generation formulation, like primal heuristics or branching rules. We report on computational exper-

iments on a number of applications and discuss what can be learned from a generic solver.

Theodore Ralphs, Lehigh University (with Matthew Galati, Michael O'Sullivan, Jiadong Wang)

Dip and DipPy: Towards a generic decomposition-based MIP solver

DIP is a software framework for simplifying the implementation of a range of decomposition-based algorithms for solving mixed integer linear optimization problems. It is based on an underlying theoretical framework that unifies a number of decomposition methods, such as Dantzig-Wolfe decomposition, Lagrangian relaxation, and cutting plane methods. Recent efforts have focused on the development of a generic decomposition-based solver, capable of automatically detecting block structure and utilizing an appropriate decomposition method to solve the problem. DipPy is a modeling language front end to DIP, which allows block structure to be explicitly identified in cases where such block structure is known to the modeler. This is done in a very natural way, making it easy for unsophisticated users to experiment with powerful methods such as column generation. In this talk, we discuss the latest developments and present computational results.

Matthew Galati, SAS Institute

The new decomposition solver in SAS/OR

This talk demonstrates the new DECOMP feature in the SAS/OR suite of optimization solvers for using decomposition-based techniques for solving linear and mixed-integer linear programs. Using the modeling language provided by the OPTMODEL procedure in SAS/OR software, a user can easily experiment with different decompositions simply by defining the partition of constraints in the original compact space. All algorithmic details in the reformulated (Dantzig-Wolfe) space are automatically managed by DECOMP. We will discuss the overall software design motivated by the goal to minimize user burden and reduce the need for algorithmic expertise. We will then present results from several client applications where DECOMP was successfully used, including results in both shared and distributed memory parallel environments.

Integer & mixed-integer programming

Wed.3.H 2033

Some bridges between algebra and integer programming

Organizer/Chair Justo Puerto, Universidad de Sevilla · Invited Session

Victor Blanco, Universidad de Granada (with Justo Puerto)

Applications of discrete optimization to numerical semigroups

In this talk we will show some connections between discrete optimization and commutative algebra. In particular we analyze some problems in numerical semigroups, which are sets of nonnegative integers, closed under addition and such that their complement is finite. In this algebraic framework, we will prove that some computations that are usually performed by applying brute force algorithms can be improved by formulating the problems as (single or multiobjective) linear integer programming. For instance, computing the omega invariant of a numerical semigroup (a measure of the primality of the algebraic object), decompositions into irreducible numerical semigroups (special semigroups with simple structure), homogeneous numerical semigroups, or the Kunz-coordinates vector of a numerical semigroups can be done efficiently by formulating the equivalent discrete optimization problem.

José-María Ucha, Universidad de Sevilla (with F. Castro, J. Gago, M. Hartillo, J. Puerto)

Algebraic tools for nonlinear integer programming problems 1: Getting started.

In this first talk we revisit a classical approach for obtaining exact solutions of some nonlinear integer problems. We treat the case of linear objective function with linear and nonlinear constraints.

Besides the test-set of some linear subpart of the problem, calculated via Gröbner bases (sometimes obtained explicitly without computation), we propose some extra ingredients. We show how to use information from the continuous relaxation of the problem, add quasi-tangent hyperplanes and use penalty functions as a guide in the search process.

María Isabel Hartillo, Universidad de Sevilla (with Jesus Gago, Justo Puerto, Jose Ucha)

Algebraic tools for nonlinear integer programming problems 2: Applications

In this second talk of the series we present how the methodology works in some real problems, namely construction of integer portfolios and redundancy allocation problems in series-parallel systems. Only in the first case the nonlinear part is of convex type. We analyse how the ideas introduced in the first talk provide promising results in computational experiments. On the other side, the combination of using test-sets and heuristics techniques opens a new approach for getting good solutions in facing huge problems.

Life sciences & healthcare

Wed.3.MA 376

Radiation therapy treatment planning

Organizer/Chair Edwin Romeijn, University of Michigan · Invited Session

Troy Long, University of Michigan (with Hilbrand Romeijn)

Beam orientation optimization in radiation therapy treatment planning

In beam orientation optimization, a small number of beam positions must be selected that allow for both a high treatment plan quality and efficient deliverability, creating a large-scale combinatorial optimization problem. Our goal is to develop an efficient and effective method for selecting high-quality coplanar or non-coplanar beam orientations for IMRT treatments that explicitly incorporates the effect of this selection on the quality of the resulting optimal dose distribution. To this end, we propose a greedy heuristic for solving a model that integrates beam selection with the so-called fluence map optimization problem (which optimizes the dose distribution given a fixed set of beams). The algorithm iteratively adds beams to the model according to a dynamically updated attractiveness measure for each remaining candidate beam. We consider measures that are based explicitly on the optimal dose distribution corresponding to the currently selected set of beams. Several specific attractiveness measures are proposed that use either first-order or both first and second-order information. Performance of the algorithm was assessed on clinical data.

Albin Fredriksson, Royal Institute of Technology

A characterization of robust radiation therapy optimization methods

A key aspect of external beam radiation therapy is the collocation of the patient anatomy and the treatment beams. Unless accounted for, systematic and random errors risk degrading the delivered treatment severely compared to the planned. We consider a minimax stochastic optimization framework that generalizes many previous methods used to account for systematic and random errors. The methods within this framework range from expected value to worst case optimization. We characterize how methods of this framework yield robust plans by studying the results of applying them to a two-dimensional phantom, and discuss how they differ from a conventional method that uses margins to account for uncertainties. For random errors, the importance of taking into account uncertainty in the probability distribution of the errors is highlighted.

Marina Epelman, University of Michigan (with Xiejun Gu, Xun Jia, Steve Jiang, Fei Peng, Edwin Romeijn)

A column generation-based algorithm for Volumetric Modulated Arc Therapy (VMAT) treatment plan optimization

External beam radiation therapy is a common treatment for many types of cancer. During such treatment, radiation is delivered with a gantry, equipped with a radiation source, that is pointed at the patient from various angles. Optimization models are commonly used in individualized treatment planning, and formulation and solution methods for such models are an area of active research. VMAT is a particular technique for delivering radiation, in which the gantry continuously rotates around the patient while the leaves of a multi-leaf collimator (MLC) move in and out of the radiation field to shape it. This technique has the potential to produce treatments of high quality similar to, e.g., Intensity Modulated Radiation Therapy (IMRT), but requiring less time for delivery. Recently, commercial systems capable of delivering VMAT treatments became available, necessitating the development of relevant treatment planning methods. We propose one such method, which uses optimization models and column generation-based heuristics to produce high-quality VMAT treatment plans that allow for dynamically adjustable gantry speed and dose rate, and MLC leaf speed constraints.

Logistics, traffic, and transportation

Wed.3.H 0106

Vehicle and crew planning

Chair Gary Froyland, University of New South Wales, Australia

Gary Froyland, University of New South Wales, Australia (with Michelle Dunbar, Cheng-Lung Wu)

Robust airline schedule planning, aircraft routing and crew pairing: An integrated scenario-based approach

For reasons of tractability, classical approaches to the airline scheduling problem have been to sequentially decompose the problem into various stages (eg. schedule generation, fleet assignment, aircraft routing, and crew pairing), with the decisions from one stage imposed upon the decision making process in subsequent stages. Such a sequential approach unfortunately fails to capture the many dependencies between the various stages, most notably between those of aircraft routing and crew pairing, and how these dependencies affect the propagation of delays through the flight network. As delays are commonly

transferred between late-running aircraft and crew, it is important that aircraft routing and crew pairing decisions are made together. The propagated delay may then be accurately estimated to minimise the overall propagated delay for the network and produce a robust solution for both aircraft and crew. We introduce a new scenario-based approach to accurately calculate and minimise the cost of propagated delay, in a framework that integrates aircraft routing, crew pairing, and re-timing, and uses delay information from multiple scenarios.

Elmar Swarat, Zuse Institute Berlin (with Ralf Borndörfer, Guillaume Sagnol)

Modeling and solving a toll enforcement problem

We present the Toll Enforcement Problem to optimize the tours of toll inspectors on German motorways. This is an integrated planning and scheduling model, consisting of a tour planning and a duty rostering part. The goal is to achieve a network-wide control proportional to the traffic distribution. We introduce a time-expanded planning graph, based on a given time discretization, where computing the tours corresponds to a Multi-Commodity flow problem. This is formulated as an IP using path variables. For the rostering problem we develop a graph model, where arcs model feasible sequences of duties. Finding feasible rosters again comes up to a Multi-Commodity flow problem in an IP formulation. By introducing coupling constraints, both problems were connected to an integrated model. We will show, that many important requirements and legal rules can be modeled by this approach. By our modeling issues the extreme complexity of our problem can be reduced to reasonable size problem instances. Computational experiments on several real-world instances indicate that we are able to solve them to a proven optimality with only a small gap.

Guvenc Sahin, Sabanci University (with Fardin Dashty Saridarq, A. Cetin Suyabatmaz)

Tactical and strategic crew planning problems in railways

We consider the tactical level planning problem in railways that determine the minimum sufficient crew resources level for one crew region at a time given the list of periodic train duties in a finite planning horizon. We formulate this problem once as a network flow problem and once as a set covering problem. The set covering version may only be attacked with a column-and-row generation algorithm, and the experimental results are not satisfactory from a computational point of view when compared to the network flow formulation. Even with complicating hard constraints that challenge the network flow formulation, the set covering problem is not easy to handle while the network flow formulations conveys optimal solutions with no additional effort. We also extend the network flow formulation to consider multiple regions simultaneously while the allocation of train duties among the regions is partially unknown. The problem is to determine the allocation and the level of minimum sufficient crew resources level coherently. The network flow formulation still provides satisfactory results, but only for a limited number of regions under consideration.

Logistics, traffic, and transportation

Wed.3.H 0111

Public transportation

Chair Marie Schmidt, Universität Göttingen

Amini Toosi Vahid, Industrial Engineering Dept. of Amirkabir University of Tehran (with Najjar Vazifedan Ala)

An integer linear programming model for bus rapid transit network design

Public transportation plays an important role in most populated cities. In Iran, the majority of people use public bus transportation within the cities. Thus, the quality of bus network services is very important. Bus Rapid Transit (BRT) is a high capacity public transit solution that can improve urban mobility. For several decades, operations research (OR) has been successfully applied to solve a wide variety of optimization problems in public transit. This paper represents an integer linear programming model to design a BRT network. The model attempts to maximize the coverage of public transportation demand. The model has been implemented to the design of BRT network in Mashhad, the second largest city of Iran. The required actual data have been collected and fed to the model. The resulting network determines the BRT routes, the BRT stations and the schedules.

Weng Hei Tou, The Chinese University of Hong Kong (with Janny M. Y. Leung)

A dial-a-ride problem for public transport using electric vehicles

With concern about environmental quality growing in the world, sustainable transportation systems, such as on-demand public transit and the usage of electric vehicles (EV), are developing in many cities. An on-demand public transport system works similar to a taxi service, but combines the servicing of customers with similar routes in the same vehicle so as to reduce operational cost and impact to the environment. The usage of EV can further reduce pollution levels. We combine these

two eco-friendly concepts to study a variant of the Dial-a-Ride problem (DARPEV), which aims to minimize the total distance travelled subject to meeting all customers' requests, and constraints on vehicle capacity, pickup/ delivery time-window, customer ride-time and battery-charging restrictions. Using EV limits the travelling time between battery recharges. The restricted charging locations and the requirement that charging must be done with no customers in-service complicate the problem, as extra variables and constraints are added. Computational results and further research directions are discussed.

Marie Schmidt, Universität Göttingen

A new model for capacitated line planning

The planning of lines and frequencies is a well-known problem in public transportation planning. Passenger-oriented approaches to line planning often determine the lines to be established, the corresponding frequencies, and the passenger routing simultaneously. This integration of the planning steps yields better results than stepwise approaches which start with an estimation of the passengers' paths by traffic-assignment procedures and then establish lines and frequencies accordingly. However, in presence of capacity constraints, integrated approaches aiming at a minimization of the overall travel time may find solutions which force some passengers to make long detours. When such a line concept is realized in practice, passengers will most likely not accept such a solution but choose a shortest route among the available ones, leading to a violation of capacity constraints. For this reason, we develop a new line planning model that allows every passenger to choose a shortest route among all available ones. We provide complexity results and an integer programming formulation for this model.

Mixed-integer nonlinear programming

Wed.3.MA 041

Quadratic integer programming

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Christoph Buchheim, TU Dortmund (with Emiliano Traversi)

Nonconvex underestimators for integer quadratic optimization

Recently, fast branch-and-bound algorithms for both convex and nonconvex integer quadratic optimization problems have been proposed that use lattice-point free ellipsoids for deriving lower bounds. In the convex case, these bounds improve those obtained from continuous relaxation. The ellipsoids are often chosen as axis-parallel ellipsoids centered in the stationary point of the objective function. In our talk, we show that in this case the resulting lower bound can be interpreted as the integer minimum of a separable quadratic nonconvex global underestimator of the objective function with the same stationary point. The best such underestimator can be computed efficiently by solving an appropriate semidefinite program. This approach can be applied to mixed-integer quadratic programming problems with box constraints, where the separable underestimator can be minimized easily, and to combinatorial optimization problems with quadratic objective functions whenever the underlying linear problem can be solved efficiently.

Long Trieu, TU Dortmund (with Christoph Buchheim)

Convex piecewise quadratic integer programming

We consider the problem of minimizing a function given as the maximum of finitely many convex quadratic functions having the same Hessian matrix. A fast algorithm for minimizing such functions over all integer vectors is presented. This algorithm can be embedded in an extended outer approximation scheme for solving general convex integer programs, where suitable quadratic approximations are used to underestimate the original objective function instead of classical linear approximations. Our algorithm is based on a fast branch-and-bound approach for convex quadratic integer programming proposed by Buchheim, Caprara and Lodi (2011). The main feature of the latter approach consists in a fast incremental computation of continuous global minima, which are used as lower bounds. We explain the generalization of this idea to the case of k convex quadratic functions. The idea is to implicitly reduce the problem to at most 2^k convex quadratic integer programs. Each node of the branch-and-bound algorithm can be processed in $O(2^k n)$. Experimental results for increasing sizes of k are shown. Compared to the standard MIQCP solver of CPLEX, running times can be improved considerably.

Hyemin Jeon, University of Wisconsin-Madison (with Jeffrey Linderoth, Andrew Miller)

Convex quadratic programming with variable bounds

The set $X = \{(x, z, v) \in \mathbb{R}_+^n \times \mathbb{B}^n \times \mathbb{R}_+ \mid v \geq x^T Q x, x_j \leq z_j \forall j\}$ for some matrix $Q \geq 0$ appears as substructure in many applications including portfolio management and data mining. We aim to obtain a good approximation of $\text{conv}(X)$, and our approach starts by reformulating the set using Cholesky factorization $Q = LL^T$. In the reformulated set $S = \{(y, t, z, v) \in \mathbb{R}^n \times \mathbb{R}_+^n \times \mathbb{B}^n \times \mathbb{R}_+ \mid v \geq \sum_j t_j, t_j \geq y_j^2 \forall j, 0 \leq$

$[L^{-T}y]_j \leq z_j \forall j$ }, the nonlinear constraints are convex and separable but the interaction between continuous and binary variables is more complicated. Our work thus far has focused on studying the set S in the case $n = 2$ denoted by S_2 . A number of valid inequalities for S_2 are derived, most of which are represented as second-order cone constraints. Computational experiments are conducted to empirically compare the obtained relaxation to $\text{conv}(S_2)$, and to demonstrate how to utilize our valid inequalities for the case $n > 2$.

Mixed-integer nonlinear programming

Wed.3.MA 042

Topics in mixed-integer nonlinear programming III

Chair Duan Li, The Chinese University of Hong Kong

Duan Li, The Chinese University of Hong Kong (with Xiaoting Sun, Xiaojin Zheng)

MIQP solvers for quadratic programs with cardinality and minimum threshold constraints: A semidefinite program approach

We consider in this research the cardinality constrained quadratic programming problem (P) that arise naturally in various real-world applications such as portfolio selection and subset selection in regression. We first investigate how to construct tighter semidefinite program (SDP) relaxation of the problem by applying a special Lagrangian decomposition scheme to the diagonal decomposition of the problem. We show that for any fixed diagonal decomposition, the dual problem can be reduced to a second-order cone program (SOCP), which is the continuous relaxation of the perspective reformulation of (P). This leads to an SDP formulation for computing the "best" diagonal decomposition in the perspective reformulation. Numerical results comparing the performance of different MIQP reformulations of the problem show that the proposed SDP approach can help to improve the performance of the standard MIQP solvers for cardinality constrained quadratic programs.

Vikas Sharma, Thapar University (with Kalpana Dahiya, Vanita Verma)

A duality based approach for a class of bilevel programming problems

This paper proposes a globally convergent algorithm for a class of bilevel programming problem where the upper level objective function is linear fractional and lower level objective function is linear with an additional restriction on decision variables that are integers for upper level and continuous for lower level. The proposed algorithm makes use of duality theory, to transform the given bilevel problem into a nonlinear programming problem, which can be solved by solving a series of linear fractional programming problems with linear constraints, to obtain a global optimal solution of the original bilevel programming problem. A numerical example is also discussed which illustrates the feasibility and efficiency of the proposed algorithm.

Geeta Kumari, Thapar University, Patiala,

Symmetric duality for multiobjective second-order fractional programs

In this paper, a pair of symmetric dual multiobjective second-order fractional programming problems is formulated and appropriate duality theorems are established. These results are then used to discuss the minimax mixed integer symmetric dual fractional programs.

Multi-objective optimization

Wed.3.H 1029

Applications of vector and set optimization

Organizer/Chair Andreas Löhne, Martin-Luther-Universität Halle-Wittenberg · Invited Session

Sonia Radjef, University USTO of Oran (with Mohand Ouamer Bibi)

The direct support method to solve a linear multiobjective problem with bounded variables

We propose a new efficient method for defining the solution set of a multiobjective problem, where the objective functions involved are linear, the set of feasible points is a set of linear constraints and the decision variables are upper and lower bounded. The algorithm is a generalization of the direct support method, for solution a linear mono-objective program. Its particularity is that it avoids the preliminary transformation of the decision variables. It handles the bounds such as they are initially formulated. The method is really effective, simple to use and permits to speed-up the resolution process. We use the suboptimal criterion of the method in single-objective programming to find the subefficient extreme points and the subweakly efficient extreme points of the problem. This algorithm is applied to solve a problem of production planning in the Ifri Dairy.

Andreas Löhne, Martin-Luther-Universität Halle-Wittenberg

BENSOLVE – A solver for multi-objective linear programs

BENSOLVE is a MOLP solver based on Benson's outer approxima-

tion algorithm and its dual variant. The algorithms are explained and the usage of the solver is demonstrated by different applications, among them applications from Mathematical Finance concerning markets with transaction costs.

Firdevs Ulus, Princeton University (with Andreas Löhne, Birgit Rudloff)

An approximation algorithm for convex vector optimization problems and its application in finance

Linear vector optimization problems (VOP) are well studied in the literature, and recently there are studies on approximation algorithms for convex VOP. We propose an approximation algorithm for convex VOP, which is an extension of Benson's outer approximation and provides both inner and outer approximation for the convex optimal frontier. The algorithm requires solving only one optimization problem in each iteration step, rather than two as in the literature. We also extend the algorithm to arbitrary solid polyhedral ordering cones. As a financial application, we consider a discrete time market model for d-asset, with proportional transaction costs, over a finite probability space. In this setting, we study the set valued approach for utility maximization, and show that this problem can be solved by reformulating it as a convex VOP and applying the proposed algorithm.

Nonlinear programming

Wed.3.H 0107

Line-search strategies

Organizer/Chair José Mario Martínez, University of Campinas · Invited Session

Ernesto G. Birgin, University of São Paulo

Spectral projected gradients: Reviewing ten years of applications

The Spectral Projected Gradient method (SPG) seeks the minimization of a smooth function over a convex set for which the projection operation can be inexpensively computed. The SPG is based on projected gradients and combines the spectral steplength with nonmonotone line searches. Since its introduction in 2000, many successful usages on a variety of fields have been reported, comprising Machine Learning, Medical Imaging, Meteorology, and Image Reconstruction, including Compressive Sensing, just to name a few. In this talk, some of those applications will be reviewed and analyzed.

Sandra Santos, State University of Campinas (with Marcia Gomes-Ruggiero, Douglas Goncalves)

An adaptive spectral approximation-based algorithm for nonlinear least-squares problems

In this work we propose an adaptive algorithm for solving nonlinear least-squares problems, based on scalar spectral matrices employed in the approximation of the residual Hessians. Besides regularizing the Gauss-Newton step and providing an automatic updating for the so-called Levenberg-Marquardt parameter, the spectral approximation has a quasi-Newton flavour, including second-order information along the generated directions, obtained from the already computed first-order derivatives. A nonmonotone line search strategy is employed to ensure global convergence, and local convergence analysis is provided as well. Comparative numerical experiments with the routines LMDER and NL2SOL put the approach into perspective, indicating its effectiveness in two collections of problems from the literature.

Natasa Krejic, University of Novi Sad (with Natasa Krklec)

Nonmonotone line search methods with variable sample sizes

Nonmonotone line search methods for minimization of unconstrained objective functions in the form of mathematical expectation are considered. Nonmonotone schemes can improve the likelihood of finding a global minimizer and convergence speed. Sample Average Approximation - SAA method transforms the expectation objective function into a real-valued deterministic function using a large sample in each iteration. The main drawback of this approach is its cost. We will analyze a couple of nonmonotone line search strategies with variable sample sizes. Two measures of progress - lack of precision and functional decrease are calculated at each iteration. Based on this two measures a new sample size is determined. Additional safe guard rule is imposed to ensure the consistency of the linear models obtained with different samples. The rule we will present allows us to increase or decrease the sample size in each iteration until we reach some neighborhood of the solution. After that the maximal sample size is used so the variable sample size strategy generates the solution of the same quality as SAA method but with significantly smaller number of functional evaluations.

Nonlinear programming

Wed.3.H 0112

Applications of optimization II

Chair Alina Fedossova, Colombian National University

Thea Göllner, TU Darmstadt (with Wolfgang Hess, Stefan Ulbrich)

Geometry optimization of branched sheet metal products

We consider the geometry optimization of branched, and potentially curved, sheet metal products. Such products can be produced continuously and in integral style by using the new technologies linear flow splitting and linear bend splitting, which are explored within the framework of the Collaborative Research Centre (CRC) 666. The geometry of such sheet metal parts can be parameterized by means of free form surfaces, more specifically, by tensor products of cubic B-splines. The mechanical behaviour is described by the three dimensional linear elasticity equations. We formulate the associated PDE-constrained problem for optimizing the stiffness of the considered structure. Then, an algorithm for solving this shape optimization problem with a globalization strategy based on cubic regularization terms is presented. Furthermore, the exact constraints of the problem are used. We conclude by presenting numerical results.

Alina Fedossova, Colombian National University (with Valery Fedosov)

Modeling of transboundary pollutant displacement for groups of emission sources

Location of emission pollution sources, together with objects or areas that require compliance with environmental norms, often leads to their disruption. The task of reducing the excess pollution emissions to the optimum is complicated with the presence of wind shifts, which weaken or strengthen the general or local contamination. One part of the pollution can be controlled to leave the territory, and, on the contrary, it is possible the invasion of pollution plumes from neighboring areas. (transboundary displacements). Wind shifts incorporated directly into a stochastic semi-infinite optimization algorithm. Environmental objects are represented as a map of zones with arbitrary boundaries. This approach includes the replacement of the original pollution sources with lots of virtual sources with a total capacity equivalent to the initial emissions. Possible local directions of wind shifts are presented in the form of maps of the streamlines of wind area, accounted later in the numerical experiment. Objective function of semi-infinite programming minimizes costs of pollution control with wind shifts.

Nonsmooth optimization

Wed.3.H 1012

Variational methods in optimization

Organizers/Chairs Pando Georgiev, University of Florida; Julian Revalski, Bulgarian Academy of Sciences · Invited Session

Nina Ovcharova, Universität der Bundeswehr München

Second-order analysis of the Moreau-Yosida and the Lasry-Lions regularizations

In this work we drop the condition of convexity and consider both Moreau-Yosida and Lasry-Lions regularizations of locally Lipschitz quadratically minorized functions. Our aim is to investigate the second-order properties of both these regularizations and to relate them to the approximated function itself. For this purpose we consider functions that admit a second-order expansion (e.g., prox-regular functions). These functions possess a generalized Hessian, but note that this property is weaker than the existence of a classical Hessian, since we suppose only the existence of the first partial derivatives. We give sufficient conditions for the regularizations to have a generalized Hessian as well. Emphasize that these results are useful for the convergence analysis of approximate numerical methods for solving nonsmooth optimization problems.

Pando Georgiev, University of Florida (with Panos Pardalos)

Global optimality conditions of first order for non-smooth functions in a Banach space

We are going to discuss our recent result regarding global optimality conditions of non-smooth locally Lipschitz functions in a Banach space. We show that the necessary conditions of first order for a local minimum of a locally Lipschitz function under constraints can be used to obtain a sufficient optimality condition of first order for a global minimum of a non-smooth function on a closed convex set in a Banach space. Namely, we use a theorem of F. Clarke and obtain a short proof and an extension to Banach spaces of a result of J.-B. Hiriart-Urruty and J.S. Ledyae. This result generalizes also previous work of A. Strekalovsky and M. Dür, R. Horst, and M. Locatelli. Special cases are considered when minimizing concave and maximum of concave functions.

Optimization in energy systems

Wed.3.MA 549

Stochastic programming in energy

Organizer/Chair Asgeir Tomasgard, NTNU · Invited Session

Gerardo Perez Valdes, NTNU (with Laureano Escudero, Marte Fødstad, Adela Pages-Bernaus, Gloria Perez, Asgeir Tomasgard)

Parallel computational implementation of a branch and fix coordination algorithm

Branch and fix coordination is an algorithm designed to solve large scale multi-stage stochastic mixed integer problems, based on the notion that the particular structure of such problems makes it so that they can be broken down into scenario groups with smaller subproblems, solvable almost independently. With this in mind, it is possible to use parallel computing techniques to solve the subproblems created: each processor solves the subproblems pertaining to a particular cluster, and then the solutions are reported to a master routine. To satisfy non-anticipativity in the master problem's binary variables, the values of the binary variables in the subproblem solutions are coordinated the entire process. The treatment of the original problem this way not only makes it faster to solve, but also allows us to solve otherwise intractable instances, where the number of binary variables is too large to be efficiently computed in a single processor. In this work, we present details and results about our computational implementation of the branch and fix coordination algorithm.

Xiang Li, Queen's University (with Paul Barton, Asgeir Tomasgard)

Stochastic nonconvex MINLP models and global optimization for natural gas production network design under uncertainty

Scenario-based stochastic nonconvex MINLP models are developed to facilitate the design of natural gas production networks under uncertainty. Here the nonconvexity comes from bilinear, quadratic and power functions involved in the equations for tracking the gas qualities and pressures. As a gas network involves large investments, a small performance gain made in the design can translate into significant increase in profits, it is desirable to solve the nonconvex MINLPs to global optimality. An extension of generalized Benders decomposition (GBD), called nonconvex generalized Benders decomposition (NGBD), is developed for the global optimization of the stochastic MINLPs. As it takes advantage of the decomposable structure of the problem, NGBD has significant computational advantage over state-of-the-art global optimization solvers (such as BARON). The advantages of the proposed stochastic nonconvex MINLP models and NGBD are demonstrated through case studies of an industrial gas production system.

Lars Hellemo, NTNU (with Paul Barton, Asgeir Tomasgard)

Stochastic programming with decision dependent probabilities

We propose an investment problem modeled as a stochastic program with decision dependent probabilities. In addition to the available production technologies, we assume there is an activity or technology available that will alter the probabilities of the discrete scenarios occurring. By investing in such technology or activity, it is possible to increase the probability of some scenarios, while reducing the probability of the remaining scenarios, or vice versa.

We also demonstrate the use of a specialized decomposition algorithm for this class of problems, using generalized Benders decomposition and relaxation of algorithms/McCormick relaxations.

We illustrate the potential usefulness and the performance of the decomposition algorithm on this class of problems through an application from the Energy business

Optimization in energy systems

Wed.3.MA 550

Stochastic equilibria in energy markets I

Organizers/Chairs Daniel Ralph, University of Cambridge; Andreas Ehrenmann, GDF SUEZ · Invited Session

Golbon Zakeri, University of Auckland (with Andy Philpott, Michael Todd)

Models for large consumer peak shaving and the impact on line pricing

We will present a mathematical programming model for a price responsive electricity user with an option to self generate. We will discuss the properties of this model and time permitting use it in a Stackelberg game where a lines company setting its tariffs is the leader and the user is a follower.

Gauthier de Maere, FEEM and CMCC (with Yves Smeers)

Modelling market liquidity in restructured power systems by stochastic Nash and generalized Nash equilibrium

The volatility of electricity prices makes its financial derivatives important instruments for asset managers. Even if the volume of deriva-

tive contracts traded on Power Exchanges has been growing since the inception of the restructuring of the sector, the liquidity of electricity markets can drastically differ depending on the situation. We analyze the situation by formulating a spatial stochastic equilibrium model of the restructured power sector with a financial market consisting of futures and financial transmission rights. We prove the existence of an equilibrium in a liquid market when the players optimize convex risk measures and show that the futures prices obey a risk neutral valuation property. We then turn to illiquidity and use a definition based on the limitation of transaction volumes. This changes the model into a Generalized Nash equilibrium (GNE) implying that several equilibrium may exist. The non arbitrage property is lost in the illiquid case. Those two features are signs of a badly functioning market. The formalism also allows one to model a market applying bid/ask spreads. Eventually we illustrate these different ideas on a six node example.

Andreas Ehrenmann, GDF SUEZ (with Yves Smeers)

Risk adjusted discounting

Capacity expansion models in the power sector were among the first applications of operations research to the industry. We introduce stochastic equilibrium versions of these models that we believe provide a relevant context for looking at the current very risky market where the power industry invests and operates. We then look at the insertion of risk related investment practices that developed with the new environment and may not be easy to accommodate in an optimization context. Specifically, we consider the use of plant specific discount rates due to different risk exposure. In a first step we introduce an iterative approach that facilitates the use of exogenously given discount rates within an capacity expansion model. This corresponds to the industry practice of assigning specific hurdle rates. As a second step we allow for discount rates being set endogenously in the equilibrium model by including stochastic discount rates in the equilibrium model. This approach is compatible with the standard CAPM from finance as long as all agents use the same (market induced) stochastic discount rate. We close with a numerical illustration.

PDE-constrained opt. & multi-level/multi-grid meth.

Wed.3.MA 415

Optimization applications in industry V

Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics - Invited Session

Arnd Roesch, University Duisburg-Essen (with Hendrik Feldhordt)

Optimal control of a chemotaxis problem

Chemotaxis describes a biological phenomenon of self organization and pattern forming of cell populations caused by chemical substances. It can be modelled by a two component reaction diffusion system in which the equations are coupled by a quasilinear cross-diffusion term. In this talk, an optimal control problem with Neumann boundary control for the chemoattractant is considered. We present results on uniform boundedness of the states, existence of optimal controls and first order necessary optimality conditions.

Antoine Laurain, TU Berlin (with Manuel Freiberger, Michael Hintermüller, André Novotny, Hermann Scharfetter)

A shape and topology optimization method for inverse problems in tomography

We propose a general shape optimization approach for the resolution of different inverse problems in tomography. For instance, in the case of Electrical Impedance Tomography (EIT), we reconstruct the electrical conductivity while in the case of Fluorescence Diffuse Optical Tomography (FDOT), the unknown is a fluorophore concentration. These problems are in general severely ill-posed, and a standard cure is to make additional assumptions on the unknowns to regularize the problem. Our approach consists in assuming that the functions to be reconstructed are piecewise constants.

Thanks to this hypothesis, the problem essentially boils down to a shape optimization problem. The sensitivity of a certain cost functional with respect to small perturbations of the shapes of these inclusions is analysed. The algorithm consists in initializing the inclusions using the notion of topological derivative, which measures the variation of the cost functional when a small inclusion is introduced in the domain, then to reconstruct the shape of the inclusions by modifying their boundaries with the help of the so-called shape derivative.

Stephanie Hokenmaier, Linde AG (with Barbara Kallenbacher)

Optimization with discontinuities and approximations in process engineering

Process simulators are indispensable in the daily work of process engineers. The Engineering Division of The Linde Group, which is one of the world leading companies in planning and building process plants, has been developing the in-house process simulation pro-

gram OPTISIM[®] for the simulation and optimization of chemical processes. Increasing demands on the optimizer concerning problem size, efficiency and robustness, especially with the occurrence of discontinuities and the use of approximations during simulation and optimization, lead to a closer look towards new optimization methods. In this context the global convergence of the filter line search of Biegler and Wächter, used in the optimizer IPOPT, was considered under the assumption of perturbed equality constraints and derivatives, which models their approximate evaluation as well as to some extent also the discontinuities. Furthermore some numerical results will be shown.

Robust optimization

Wed.3.MA 004

Applications of robust optimization V

Chair Adrian Sychau, TU Darmstadt

Akiko Takeda, Keio University (with Takafumi Kanamori, Hiroyuki Mitsugi)

Robust optimization-based classification method

The goal of binary classification is to predict the class (e.g., +1 or -1) to which new observations belong, where the identity of the class is unknown, on the basis of a training set of data containing observations whose class is known. A wide variety of machine learning algorithms such as support vector machine (SVM), minimax probability machine (MPM), Fisher discriminant analysis (FDA), exist for binary classification. The purpose of this paper is to provide a unified classification model that includes the above models through a robust optimization approach. This unified model has several benefits. One is that the extensions and improvements intended for SVM become applicable to MPM and FDA, and vice versa. Another benefit is to provide theoretical results to above learning methods at once by dealing with the unified model. We also propose a non-convex optimization algorithm that can be applied to non-convex variants of existing learning methods and show promising numerical results.

Adrian Sychau, TU Darmstadt (with Stefan Ulbrich)

Shape optimization under uncertainty employing a second order approximation for the robust counterpart

We present a second order approximation for the robust counterpart of general uncertain NLP with state equation given by a PDE. We show how the approximated worst-case functions, which are the essential part of the approximated robust counterpart, can be formulated as trust-region problems that can be solved efficiently. Also, the gradients of the approximated worst-case functions can be computed efficiently combining a sensitivity and an adjoint approach. However, there might be points where these functions are nondifferentiable. Hence, we introduce an equivalent formulation of the approximated robust counterpart (as MPEC), in which the objective and all constraints are differentiable. This formulation can further be extended to model the presence of actuators that are capable of applying forces to a structure in order to counteract the effects of uncertainty. The method is applied to shape optimization in structural mechanics to obtain optimal solutions that are robust with respect to uncertainty in acting forces and material parameters. Numerical results are presented.

Sparse optimization & compressed sensing

Wed.3.H 1028

Structured models in sparse optimization

Organizer/Chair John Duchi, University of California, Berkeley - Invited Session

Rodolphe Jenatton, CNRS - CMAP (with Francis Bach, Julien Mairal, Guillaume Obozinski)

Proximal methods for hierarchical sparse coding and structured sparsity

Sparse coding consists in representing signals as sparse linear combinations of atoms selected from a dictionary. We consider an extension of this framework where the atoms are further assumed to be embedded in a tree. This is achieved using a recently introduced tree-structured sparse regularization norm, which has proven useful in several applications. This norm leads to regularized problems that are difficult to optimize, and we propose in this paper efficient algorithms for solving them. More precisely, we show that the proximal operator associated with this norm is computable exactly via a dual approach that can be viewed as the composition of elementary proximal operators. Our procedure has a complexity linear, or close to linear, in the number of atoms, and allows the use of accelerated gradient techniques to solve the tree-structured sparse approximation problem at the same computational cost as traditional ones using the L1-norm. We also discuss extensions of this dual approach for more general settings of structured

sparsity. Finally, examples taken from image/video processing and topic modeling illustrate the benefit of our method.

Minh Pham, Rutgers University (with Xiaodong Lin, Andrzej Ruszczyński)

Alternating linearization for structured regularization problems

We adapt the alternating linearization method for proximal decomposition to structured regularization problems, in particular, to the generalized lasso problems. The method is related to two well-known operator splitting methods, the Douglas–Rachford and the Peaceman–Rachford method, but it has descent properties with respect to the objective function. Its convergence mechanism is related to that of bundle methods of nonsmooth optimization. We also discuss implementation for very large problems, with the use of specialized algorithms and sparse data structures. Finally, we present numerical results for several synthetic and real-world examples, including a three-dimensional fused lasso problem, which illustrate the scalability, efficacy, and accuracy of the method.

John Duchi, University of California, Berkeley (with Elad Hazan, Yoram Singer)

Adaptive subgradient methods for stochastic optimization and online learning

We present a new family of subgradient methods that dynamically incorporate knowledge of the geometry of the data observed in earlier iterations to perform more informative gradient-based learning. Metaphorically, the adaptation allows us to find needles in haystacks in the form of very predictive but rarely seen features. Our paradigm stems from recent advances in stochastic optimization and online learning which employ proximal functions to control the gradient steps of the algorithm. We describe and analyze an apparatus for adaptively modifying the proximal function, which significantly simplifies setting a learning rate and results in regret guarantees that are provably as good as the best proximal function that can be chosen in hindsight. We give several efficient algorithms for empirical risk minimization problems with common and important regularization functions and domain constraints. We experimentally study our theoretical analysis and show that adaptive subgradient methods significantly outperform state-of-the-art, yet non-adaptive, subgradient algorithms.

Stochastic optimization

Wed.3.MA 141

Algorithms and applications for stochastic programming

Organizer/Chair Yongpei Guan, University of Florida - Invited Session

Zhili Zhou, IBM Research

A network based model for traffic sensor placement with implications on congestion observation

In this paper, we define and solve the traffic sensor placement problem for congestion observation, which targets to place the minimum number and location of traffic sensors in order to infer all traffic flow information in a dynamic changing congestion area. To handle uncertain traffic flow, we formulate this problem as a stochastic mixed-integer programming problem. We first study the combinatorial structure for traffic arc sensor placement to achieve full network coverage without historical data in a given traffic network. Then, we present the relationship between the traffic sensor placement for full network coverage in the deterministic setting and for dynamic congestion area observation. A sampling approximation algorithm is developed to solve the problem with budget constraints. The paper also provides a number of illustrative examples to demonstrate the effectiveness of the proposed methodology.

Ruiwei Jiang, University of Florida (with Yongpei Guan)

Optimization under data-driven chance constraints

Chance constraint is an effective and convenient modeling tool of decision making in uncertain environment. Unfortunately, the solution obtained from a chance-constrained optimization problem might be questionable due to the accessibility of the probability distribution of the random parameters. Usually, decision makers have no access to the distribution itself, but can only observe a series of data sampled from the true (while ambiguous) distribution. In this talk, we develop exact approaches to deal with the data-driven chance constraints (DCC). Starting from the historical data, we construct two types of confidence sets for the ambiguous distribution through statistical estimation of its moments and density functions, respectively. We then formulate DCC as a robust version of chance constraints by allowing the ambiguous distribution to run adversely within its confidence set. By deriving equivalent reformulations, we show that DCC with both (moment- and density-based) confidence sets can be efficiently solved. In addition, we depict

the relation between the risk level of DCC and the sample size of historical data, which can a priori determine the robustness of DCC.

Guzin Bayraksan, University of Arizona (with David Morton, Peguy Pierre-Louis)

A sequential bounding method for a class of two-stage stochastic programs

In this talk, we present an algorithm for two-stage stochastic programming with a convex second stage program and with uncertainty in the right-hand side. The algorithm draws on techniques from deterministically-valid bounding and approximation methods as well as sampling-based approaches. In particular, we sequentially refine a partition of the support of the random vector and, through Jensen's inequality, generate deterministically-valid lower bounds on the optimal objective function value. An upper bound estimator is formed through a stratified Monte Carlo sampling procedure that includes the use of a control variate variance reduction scheme. We present stopping rules that ensure an asymptotically valid confidence interval on the quality of the proposed solution and illustrate the algorithm via computational results.

Stochastic optimization

Wed.3.MA 144

Network design, reliability, and PDE constraints

Chair Olga Myndyuk, New Jersey State University Rutgers

Olga Myndyuk, New Jersey State University Rutgers

Stochastic network design under probabilistic constraint with continuous random variables.

Stochastic network optimization problem is formulated, where the demands at the nodes are continuously distributed random variables. The problem is to find optimal node and arc capacities under probabilistic constraint that insures the satisfiability of all demands on a high probability level. The large number of feasibility inequalities is reduced to a much smaller number (elimination by network topology), equivalent reformulation takes us to a specially structured LP. It is solved by the combination of an inner and an outer algorithm providing us with both lower and upper bounds for the optimum in each iteration. Numerical example is presented. The network design method is applicable to find optimal capacity expansion problems in interconnected power systems, water supply, traffic, transportation, evacuation and other networks.

Zuzana Šabartová, Chalmers University of Technology (with Pavel Popela)

Spatial decomposition for differential equation constrained stochastic programs

When optimization models are constrained by ordinary or partial differential equations (ODE or PDE), numerical method based on discretising domain are required to obtain non-differential numerical description of the differential parts; we chose the finite element method. The real problems are often very large and exceed computational capacity. Hence, we employ the progressive hedging algorithm (PHA) – an efficient decomposition method for solving scenario-based stochastic programs – which can be implemented in parallel to reduce the computing time. A modified PHA was used for an original concept of spatial decomposition based on mesh created for approximating differential constraints. We solve our problem with raw discretization, decompose it into overlapping parts of the domain, and solve it again iteratively by PHA with finer discretization – using values from the raw discretization as boundary conditions – until a given accuracy is reached.

The spatial decomposition is applied to a civil engineering problem: design of beam cross section dimensions. The algorithms are implemented in GAMS and the results are evaluated by width of overlap and computational complexity.

Rasool Tahmasbi, Amirkabir University of Technology (with S. Mehdi Hashemi)

Network flow problems with random arc failures

Networks have been widely used for modeling real-world problems such as communication, transportation, power, and water networks, which are subject to component failures. We consider stochastic network flows, in which the arcs fail with some known probabilities. In contrast to previous research that focuses on the evaluation of the expected maximum flow value in such networks, we consider the situation in which a flow must be implemented before the realization of the uncertainty. We present the concept of expected value of a given flow and seek for a flow with maximum expected value. We show the problem of computing the expected value of a flow is NP-hard. We examine the "value of information", as the relative increase in the expected flow value if we allow implementing a maximum flow after the uncertainty is revealed. We show that the value of information can be around 61 % on some instances. While it is significantly hard to compute the expected maximum flow value and to determine a flow with maximum expected value, we apply a simple simulation-based method to approximate these

two values. We give computational results to demonstrate the ability of this method.

Telecommunications & networks

Wed.3.H 3002

Local access networks

Organizer/Chair [Stefan Gollwitzer, University of Vienna](#) · Invited Session

[Stefan Gollwitzer, University of Vienna](#) (with [Bernard Gendron, Ivana Ljubic](#))

Capacitated network design with facility location

We consider a network design problem that arises in the design of last mile telecommunication networks. It combines the capacitated network design problem (CNDP) with the single-source capacitated facility location problem (SSCFLP). We will refer to it as the Capacitated connected facility location problem (CapConFL). We develop a basic integer programming model based on multi-commodity flows. Based on valid inequalities for the subproblems, CNDP and SSCFLP, we derive several (new) classes of valid inequalities for the CapConFL. We use them in a branch-and-cut framework and show their applicability on a set of benchmark instances.

[Mohsen Rezapour, Technical University of Berlin](#) (with [Andreas Bley, S. Mehdi Hashemi](#))

Approximation algorithms for connected facility location with buy-at-bulk edge costs

We consider a generalization of the Connected Facility Location problem (ConFL), where we need to design a capacitated network with a tree configuration to route client demands to open facilities. In addition to choosing facilities to open and connecting them by a Steiner tree, where each edge of the Steiner tree has infinite capacity, we need to buy cables from an available set of cables with different costs and capacities to route all demands of clients to open facilities via individual trees. We assume that the cable costs obey economies of scale. The objective is to minimize the sum of facility opening, connecting the open facilities and cable installation costs. In this presentation, we give the first approximation algorithm for the problem with K different types of cables. We also consider the simplified version of the problem where capacity of an edge is provided in multiples of only one cable type and give a better constant factor approximation algorithm for this case.

[Ashwin Arulsekaran, TU Berlin](#) (with [Olaf Maurer, Martin Skutella](#))

An incremental algorithm for the facility location problem

We are given an instance of a facility location problem. We provide an incremental algorithm to obtain a sequence of customers and facilities along with their assignments. The algorithm guarantees that the cost of serving the first k customers in the sequence with their assigned facilities in the sequence is within a constant factor from the optimal cost of serving any k customers. The problem finds applications in facility location problems equipped with planning periods, where facilities are opened and customers are served in an incremental fashion.

Variational analysis

Wed.3.H 2035

Nonsmooth analysis with applications in engineering

Organizer/Chair [Radek Cibulka, University of Limoges](#) · Invited Session

[Alfredo Iusem, Instituto de Matemática Pura e Aplicada](#) (with [Roger Behling](#))

The effect of calmness on the solution set of nonlinear equalities

We address the problem of solving a continuously differentiable nonlinear system of equations under the condition of calmness. This property, called also upper Lipschitz continuity in the literature, can be described as a local error bound, and is being widely used as a regularity condition in optimization. Indeed, it is known to be significantly weaker than classic regularity assumptions, which imply that solutions are isolated. We prove that under this condition, the rank of the Jacobian of the function that defines the system of equations must be locally constant on the solution set. As a consequence, we conclude that, locally, the solution set must be a differentiable manifold. Our results are illustrated by examples and discussed in terms of their theoretical relevance and algorithmic implications.

[Amos Uderzo, University of Milano-Bicocca](#)

On some calmness conditions for nonsmooth constraint systems

In various contexts of mathematical programming, constraints appearing in optimization problems, which depend on parameters, can be formalized as follows

$$f(p, x) \in C,$$

where $f : P \times X \rightarrow Y$ and $C \subset Y$ are given problem data, and p plays the role of a parameter. Useful insights on the problem behaviour (stability

and sensitivity) can be achieved by a proper analysis of the corresponding feasible set mapping, i.e. $S : P \rightarrow 2^X$

$$S(p) = \{x \in X : f(p, x) \in C\}.$$

In this vein, whenever P and X have a metric space structure, a property of S playing a crucial role, both from the theoretical and the computational viewpoint, is calmness. Mapping S is said to be calm at (p_0, x_0) if $x_0 \in S(p_0)$ and there exist $r, \zeta > 0$ and $l \geq 0$ such that

$$S(p) \cap B(x_0, r) \subseteq B(S(p_0), l d(p, p_0)), \forall p \in B(p_0, \zeta),$$

where $B(A, r) = \{x \in X : \inf_{a \in A} d(x, a) \leq r\}$. This talk is devoted to the analysis of conditions for the calmness of S . Such task is carried out by referring to recent developments of variational analysis. Emphasis is given to the case in which mapping f defining S is nonsmooth.

[Radek Cibulka, University of Limoges](#) (with [Samir Adly, Ji?i Outrata](#))

Quantitative stability of a generalized equation: Application to non-regular electrical circuits

Given matrices $B \in \mathbb{R}^{n \times m}$, $C \in \mathbb{R}^{m \times n}$, and mappings $f : \mathbb{R}^n \rightarrow \mathbb{R}^n$, $F : \mathbb{R}^m \rightarrow \mathbb{R}^m$ with $m \leq n$, consider the problem of finding for a vector $p \in \mathbb{R}^n$ the solution $z \in \mathbb{R}^n$ to the inclusion

$$p \in f(z) + BF(Cz). \quad (1)$$

Denote by Φ the set-valued mapping from \mathbb{R}^n into itself defined by $\Phi(z) = f(z) + BF(Cz)$ whenever $z \in \mathbb{R}^n$. Our aim is to investigate stability properties such as Aubin continuity, calmness and isolated calmness of the solution mapping $\Psi := \Phi^{-1}$. Under appropriate assumptions, the verifiable conditions ensuring these properties are given in terms of the input data f, F, B and C . We illustrate our consideration on a particular examples arising from electronics.

Variational analysis

Wed.3.H 2051

Some stability aspects in optimization theory

Organizers/Chairs [Abderrahim Hantoute, University of Chile](#); [Rafael Correa, Universidad de Chile](#) · Invited Session

[Abderrahim Hantoute, University of Chile](#) (with [Rafael Correa](#))

On convex relaxation of optimization problems

We relate a given optimization problem $\inf_X f$ to its lsc convex relaxation $\inf_X (cl - co)(f)$; here $(cl - co)(f)$ is the lsc convex hull of f . We establish a complete characterization of the solutions set of the relaxed problem by means exclusively of "some kind" of the solution of the initial problem. Consequently, under some natural conditions, of coercivity type, this analysis yields both existence and characterization of the solution of the initial problem. Our main tools rely on the subdifferential analysis of the so-called Legendre-Fenchel function.

[C. H. Jeffrey Pang, National University of Singapore](#)

First order analysis of set-valued maps and differential inclusions

The framework of differential inclusions encompasses modern optimal control and the calculus of variations. Its analysis requires the use of set-valued maps. For a set-valued map, the tangential derivative and coderivatives separately characterize a first order sensitivity analysis property, or more precisely, a pseudo strict differentiability property. The characterization using tangential derivatives requires fewer assumptions. In finite dimensions, the coderivative characterization establishes a bijective relationship between the convexified limiting coderivatives and the pseudo strict derivatives. This result can be used to estimate the convexified limiting coderivatives of limits of set-valued maps. We apply these results to the study of differential inclusions by calculating the tangential derivatives and coderivatives of the reachable map, which leads to the subdifferential and subderivative dependence of the value function in terms of the initial conditions. These results in turn furthers our understanding of the Euler-Lagrange and transversality conditions in differential inclusions.

[Vladimir Shikhman, RWTH Aachen University](#)

Implicit vs. inverse function theorem in nonsmooth analysis

We study the application of implicit and inverse function theorems to systems of complementarity equations. The goal is to characterize the so-called topological stability of those systems. Here, stability refers to homeomorphy invariance of the solution set under small perturbations of the defining functions. We discuss the gap between the nonsmooth versions of implicit and inverse function theorems in the complementarity setting. Namely, for successfully applying the nonsmooth implicit function theorem one needs to perform first a linear coordinate transformation. We illustrate how this fact becomes crucial for the nonsmooth analysis.

Approximation & online algorithms

Thu.1.H 3010

Approximation algorithms

Chair Naonori Kakimura, University of Tokyo

David Williamson, Cornell University (with James Davis)

A dual-fitting $\frac{3}{2}$ -approximation algorithm for some minimum-cost graph problems

In a recent paper, Couëtoux gives a beautiful $\frac{3}{2}$ -approximation algorithm to the problem of finding a minimum-cost set of edges such that each connected components has at least k vertices in it. The algorithm improved on previous 2-approximation algorithms for the problem. In this paper, we show how to reinterpret Couëtoux's analysis as dual-fitting and also show how to generalize the algorithm to a broader class of graph problems previously considered in the literature.

Stavros Kolliopoulos, University of Athens (with Isolde Adler, Dimitrios Thilikos)

Planar disjoint-paths completion

Take any graph property represented by a collection P of graphs. The corresponding completion problem asks typically for the minimum number of edges to add to a graph so that it belongs to P . Several such problems have been studied in the literature.

We introduce the completion version of Disjoint Paths on planar graphs. Given a plane graph G , k pairs of terminals, and a face F of G , find the minimum set of edges, if one exists, to be added inside F so that the embedding remains planar and the pairs become connected by k disjoint paths in the augmented network.

We give an explicit upper bound on the number of additional edges needed if a solution exists. This bound is a function of k , independent of the size n of G . Second, we show that the problem is fixed-parameter tractable, i.e., it can be solved in time $f(k)poly(n)$.

Naonori Kakimura, University of Tokyo (with Kazuhisa Makino, Kento Seimi)

Computing knapsack solutions with cardinality robustness

In this paper, we study the robustness over the cardinality variation for the knapsack problem. For the knapsack problem and a positive number $\alpha \leq 1$, we say that a feasible solution is α -robust if, for any positive integer k , it includes an α -approximation of the maximum k -knapsack solution, where a k -knapsack solution is a feasible solution that consists of at most k items. In this talk, we show that, for any $\epsilon > 0$, the problem of deciding whether the knapsack problem admits a $(\nu + \epsilon)$ -robust solution is weakly NP-hard, where ν denotes the rank quotient of the corresponding knapsack system. Since the knapsack problem always admits a ν -robust knapsack solution, this result provides a sharp border for the complexity of the robust knapsack problem. On the positive side, we show that a max-robust knapsack solution can be computed in pseudo-polynomial time, and present a fully polynomial-time approximation scheme (FPTAS) for computing a max-robust knapsack solution.

Combinatorial optimization

Thu.1.H 3004

Optimization and enumeration

Organizers/Chairs Jaroslav Nesetril, Charles University Prague; Martin Loeb, Charles University · Invited Session

Patrice Ossona de Mendez, CNRS (with Jaroslav Nesetril)

Large structured induced subgraphs with close homomorphism statistics

A particular attention has been recently devoted to the study of the graph homomorphism statistics. Let $\text{hom}(F, G)$ denote the number of homomorphisms of F to G . The problem we address here is whether a graph G contains an induced subgraph $G[A]$ such that:

- for every small test graph F , $\text{hom}(F, G[A])$ is not “too different” from $\text{hom}(F, G)$:

$$|F| \leq p \implies \log \text{hom}(F, G[A]) > (1 - \epsilon) \log \text{hom}(F, G);$$

- the subgraph $G[A]$ is highly structured in the sense that it is obtained from a small graph H (of order at most $C(p, \epsilon)$) by applying some blowup-like operations.

We prove that classes of graphs which are nowhere dense (meaning that for every integer p there is a p subdivision of a finite complete graph that is isomorphic to no subgraph of a graph in \mathcal{C}) have the property that for every integer p and every $\epsilon > 0$ every sufficiently large graph in the class has such an induced subgraph.

Michael Chertkov, Los Alamos National Laboratory (with Adam Yedidia)

Computing the permanent with belief propagation

We discuss schemes for exact and approximate computations of permanents, and compare them with each other. Specifically, we analyze the Belief Propagation (BP) approach and its Fractional BP generalization to computing the permanent of a non-negative matrix. Known

bounds and conjectures are verified in experiments, and some new theoretical relations, bounds and conjectures are proposed.

Amin Coja-Oghlan, University of Warwick (with Konstantinos Panagiotou)

Catching the k -NAESAT threshold

The best current estimates of the thresholds for the existence of solutions in random CSPs mostly derive from the first and the second moment method. Yet apart from a very few exceptional cases these methods do not quite yield matching upper and lower bounds. Here we present an enhanced second moment method that allows us to narrow the gap to an additive $2^{-(1-\alpha_k(1))k}$ in the random k -NAESAT problem, one of the standard benchmarks in the theory of random CSPs. This is joint work with Konstantinos Panagiotou.

Combinatorial optimization

Thu.1.H 3005

Robust network design

Organizer/Chair Michael Juenger, Universität zu Köln · Invited Session

Manuel Kutschka, RWTH Aachen University (with Grit Claßen, Arie Koster, Issam Tahiri)

Robust metric inequalities for network design under demand uncertainty

In this talk, we generalize the metric inequalities for the (classical) network design problem to its robust counter-part. Furthermore, we show that they describe the robust network design problem completely in the capacity space, where a straight-forward generalization of the classical metric inequalities is not sufficient. We present a polynomial algorithm to separate robust metric in-equalities as model inequalities for the capacity space formulation of the robust network design problem. In computational experiments, we analyze the added value of this new class of valid inequalities within a branch-and-cut approach to solve the robust network design problem.

Daniel Schmidt, Universität zu Köln (with Eduardo Alvarez-Miranda, Valentina Cacchiani, Tim Dorneth, Michael Jünger, Frauke Liers, Andrea Lodi, Tiziano Parrini)

Single commodity robust network design: Models and algorithms

We study a model that aims at designing cost-minimum networks that are robust under varying demands: Given an undirected graph G , a finite number of scenarios and a cost function, we want to find the cheapest possible capacity installation on the edges of G such that the demands of all scenarios can be satisfied by a single-commodity flow. This problem is known in the literature as *single commodity robust network design*. We propose two tools for optimizing over this model: Firstly, we develop a large neighborhood search heuristic that allows for trading computing time for solution quality. Secondly, we show how to optimize exactly with a branch-and-cut algorithm that is based on a new integer programming formulation. Both approaches undergo computational evaluation.

Laura Sanità, University of Waterloo (with Jaroslaw Byrka, Fabrizio Grandoni, Thomas Rothvoss)

Steiner tree approximation via iterative randomized rounding

The Steiner tree problem is one of the most fundamental NP-hard problems: given a weighted undirected graph and a subset of terminal nodes, find a minimum-cost tree spanning the terminals. In a sequence of papers, the approximation ratio for this problem was improved from 2 to 1.55 [Robins, Zelikovsky-05]. All these algorithms are purely combinatorial. In this talk we present an LP-based approximation algorithm for Steiner tree with an improved approximation factor. Our algorithm is based on a, seemingly novel, iterative randomized rounding technique. We consider an LP relaxation of the problem, which is based on the notion of directed components. We sample one component with probability proportional to the value of the associated variable in a fractional solution: the sampled component is contracted and the LP is updated consequently. We iterate this process until all terminals are connected. Our algorithm delivers a solution of cost at most $\ln(4) + \epsilon < 1.39$ times the cost of an optimal Steiner tree.

Combinatorial optimization

Thu.1.H 3008

Resource placement in networks

Organizer/Chair David Johnson, AT&T Labs - Research · Invited Session

David Johnson, AT&T Labs - Research (with Lee Breslau, Ilias Diakonikolas, Nick Duffield, Yu Gu, Mohammadtaghi Hajiaghayi, Howard Karloff, Mauricio Resende, Subharata Sen)

Disjoint path facility location: Theory and practice

We consider the following problem: Given a directed graph $G = (V, A)$ with weights on the arcs, together with subsets C (customers) and F (potential facility locations) of V , find a subset F' of F such that, for every c in C , either c is in F' or there exist two vertices f, f' in F' such

that no shortest path from c to f shares any vertex other than c with any shortest path from c to f' (a restriction required when routing is done by the OSPF protocol with path-splitting). This “cover by pairs” problem has potential applications to network monitoring and to the distribution of time-critical streaming content. Theoretical results suggest that no algorithm can be guaranteed to get within even a polylogarithmic factor of optimal for our problem, and MIP-based optimization approaches become infeasible for graphs with more than about 100 vertices. However a collection of heuristics we devised succeeded in finding optimal solutions to all the instances in our testbed of synthetic and real-world instances, with sizes ranging up to 1000 vertices, as verified by computing a (much easier) MIP-based lower bound. We describe the applications, theory, algorithms, bounds, and experimental results.

David Applegate, AT&T Labs – Research (with Aaron Archer, Vijay Gopalkrishnan, Seungjoon Lee, K.k. Ramakrishnan)

Using an exponential potential function method to optimize video-on-demand content placement

For a large-scale Video-on-Demand service, as the library size grows, it becomes important to balance the disk space necessary to store content locally at the requesting node with the bandwidth required to serve requests from remote nodes. This gives rise to the problem of deciding which content to place at which serving nodes, taking into account the resource constraints (disk and bandwidth) and content attributes (request patterns, size, and bandwidth).

We model this optimization problem as a mixed-integer program. However, even for moderately large instances (20,000 videos, 50 serving nodes), the linear relaxation becomes intractable for off-the-shelf linear programming solvers, both in terms of time and memory use. Instead, we approximately solve the linear relaxation by using a Lagrangian decomposition approach based on exponential potential functions, and then round that solution to an integer solution.

Computational experiments on a testbed of synthetic and real-world instances show that this decomposition approach typically reduces the running time by orders of magnitude, while achieving solutions within 2% of optimal with no constraint violated by more than 1%.

Combinatorial optimization

Thu.1.H 3012

Exact algorithms for hard problems

Chair Réal Carbonneau, GÉRAD and HEC Montréal (Université de Montréal)

Réal Carbonneau, GÉRAD and HEC Montréal (Université de Montréal) (with Gilles Caporossi, Pierre Hansen)

Globally optimal clusterwise regression by branch and bound optimization with heuristics, sequencing and ending subset

Clusterwise regression is a clustering technique which fits multiple lines or hyperplanes to mutually exclusive subsets of observations. It is a cubic problem, but can be re-formulated as a mixed logical-quadratic programming problem. An extension and generalization of Brusco's repetitive branch and bound algorithm (RBBA) is proposed for global optimization of the clusterwise regression problem. Branch and bound optimization is enhanced by heuristics, observation sequencing and ending subset optimization. Heuristics can improve the upper bound, observation sequencing can improve the search path and can increase fathoming, while the ending subsets can recursively strengthen the lower bounds of the search. Additionally, symmetry breaking and incremental regression calculations are employed to further speed up the optimization. Experiments demonstrate that the proposed optimization strategy is significantly faster than CPLEX and that the combination of all the components is significantly faster than each one individually. The proposed approach can optimize much larger datasets than what is possible using CPLEX.

Margena Fügenschuh, Beuth University of Applied Sciences (with Michael Armbruster, Christoph Helmburg, Alexander Martin)

LP and SDP branch-and-cut algorithms for the minimum graph bisection problem: A computational comparison

While semidefinite relaxations are known to deliver good approximations for combinatorial optimization problems like graph bisection, their practical scope is mostly associated with small dense instances. For large sparse instances, cutting plane techniques are considered the method of choice. These are also applicable for semidefinite relaxations via the spectral bundle method, which allows to exploit structural properties like sparsity. In order to evaluate the relative strengths of linear and semidefinite approaches for large sparse instances, we set up a common branch-and-cut framework for linear and semidefinite relaxations of the minimum graph bisection problem. Extensive numerical experiments show that our semidefinite branch-and-cut approach is a

superior choice to the classical simplex approach for large sparse test instances from VLSI design and numerical optimization.

Adelaide Cerveira, UTAD (with Agostinho Agra, Fernando Bastos, Joaquim Gromicho)

A two-stage branch and bound algorithm to solve truss topology design problems

Our paper considers a classic problem in the field of Truss topology design, the goal of which is to determine the stiffest truss, under a given load, with a bound on the total volume and discrete requirements in the cross-sectional areas of the bars. To solve this problem we propose a new two-stage branch and bound algorithm. In the first stage we perform a branch and bound algorithm on the nodes of the structure. This is based on the following dichotomy study: either a node is in the final structure or not. In the second stage, a branch and bound on the bar areas is conducted. The existence or otherwise of a node in this structure is ensured by adding constraints on the cross-sectional areas of its incident bars. For stability reasons, when a free node exists in the structure, we impose that at least two incident bars on it. These constraints are added during the first stage and lead to a tight model. We report the computational experiments conducted to test the effectiveness of this two-stage approach, enhanced by the rule to ensure stability, as compared to a classical branch and bound algorithm, where branching is only performed on the bar areas.

Combinatorial optimization

Thu.1.H 3013

Combinatorial optimization in railways II

Organizer/Chair Ralf Borndörfer, Zuse Institute Berlin · Invited Session

Ronny Hansmann, TU Braunschweig (with Uwe Zimmermann)

Minimal shunting operations for freight train composition

Planning freight train schedules in dense rail networks provides an enormous challenge. Resulting optimization models include a tremendous number of eligible train routes and departure times restricted by sparse infrastructure capacities. From our ongoing cooperation with the Deutsche Bahn (DB) within a three-year project, we outline first results focusing on the composition of rail cars in freight trains. According to requests of the customers of the DB, rail cars are routed from origin to destination throughout Germany by assigning them to a suitable sequence of previously scheduled freight trains. Additionally, the sequence of the rail cars within a freight train may be chosen. The real challenge consists in assigning rail cars to freight trains with choice of their sequence within the train minimizing the total number of time-consuming shunting operations in the visited rail yards. To our knowledge, the resulting NP-hard problem was previously not studied in the literature. We present new mixed integer programming formulations, some heuristics as well as computational experience for practical data from the DB. We conclude the talk with some remarks on future research.

Andreas Bärmann, FAU Erlangen-Nürnberg (with Andreas Heidt, Alexander Martin, Sebastian Pokutta, Christoph Thurner)

Approximate robust optimization and applications in railway network expansion

This talk is concerned with the application of robust optimization to railway network expansion planning. We introduce a methodology that linearizes the elliptic uncertainty sets describing the demand uncertainty to maintain the linearity of the problem.

Dealing with data uncertainty is of great importance in infrastructure development which can be affected by inaccuracy in demand forecast. The robust optimization framework immunizes the model against all data scenarios in a given uncertainty set. In this talk we introduce a methodology that linearizes elliptic uncertainty sets. For this purpose we apply the approach of Ben-Tal and Nemirovski for the linearization of the second order cone. In the case of a linear optimization model this allows for solving the robustified model as a linear program again. The benefits especially arise in discrete optimization, as we can maintain the warm start capabilities of the simplex method.

We present computational results for an implementation of the method in the context of a railway network expansion application in cooperation with Deutsche Bahn AG. We also outline applications in air traffic management and energy systems optimization.

Torsten Klug, Zuse Institute Berlin (with Ralf Borndörfer, Armin Fügenschuh, Thomas Schlechte)

An approach for solving the freight train routing problem

We consider the following freight train routing problem. Given is a transportation network with fixed routes for passenger trains and a set of freight train requests, each defined by an origin and destination station pair. The objective is to calculate a feasible route for each freight train such that a sum of expected delays and running times is minimal. Previous research concentrated on microscopic train routings for junctions or major stations. Only recently approaches were developed

to tackle larger corridors or even networks. We investigate the routing problem from a strategic perspective, calculating the routes in a macroscopic transportation network. In this terms macroscopic means complex structures are aggregated into smaller elements and the departure and arrival times of freight trains are approximated. The problem has a strategic character since it asks only for a rough routing through the network without the precise timings. We propose a best insertion heuristic and a mixed integer programming model for the freight train routing problem, compare them, and present some computational results using different state of the art MIP-solvers.

Combinatorial optimization

Thu.1.H 3021

Smoothed analysis of algorithms

Organizers/Chairs Alantha Newman, DIMACS; Heiko Röglin, University of Bonn · Invited Session

Tjark Vredeveld, Maastricht University (with Tobias Brunsch, Heiko Röglin, Cyriel Rutten)

Smoothed analysis of local search

In this talk, we consider the concept of smoothed performance guarantees and apply it to the performance guarantees of local optima. Smoothed analysis was introduced by Spielman and Teng (JACM 2004) as a hybrid between worst case and average case analysis, to explain the good behavior of algorithms that have a bad worst case performance. Up to now, smoothed analysis has been mainly applied to the running time of algorithms. We will use smoothed analysis to investigate the approximation ratio of an algorithm, that is, the ratio between the value of an approximate solution and the optimal solution value. In the last decade, there has been a strong interest in understanding the worst case behavior of local optimal solutions. We extend this research by investigating whether or not this worst case behavior is robust. We will apply the concept of smoothed performance guarantees to several local optima for some scheduling problems. As a by-product, we also get a smoothed price of anarchy for some scheduling games.

Tobias Brunsch, University of Bonn (with Heiko Röglin)

Improved smoothed analysis of multiobjective optimization

We present several new results about smoothed analysis of multiobjective optimization problems. Particularly, we consider problems in which d linear and one arbitrary objective function are to be optimized over a set $\mathcal{S} \subseteq \{0, 1\}^n$ of feasible solutions. The coefficients of the linear objectives are subject to random perturbations specified by an adversary whose power is limited by a perturbation parameter ϕ . We improve the previously best known bound for the smoothed number of Pareto-optimal solutions to $O(n^{2d}\phi^d)$ for natural perturbation models. Additionally, we show that for any constant c the c -th moment of the smoothed number of Pareto-optimal solutions is bounded by $O((n^{2d}\phi^d)^c)$. This improves the previously best known bounds significantly. Furthermore, we address the criticism that the perturbations in smoothed analysis destroy the zero-structure of problems by giving a polynomial bound for the smoothed number of Pareto-optimal solutions for zero-preserving perturbations. One consequence of this result is that the smoothed number of Pareto-optimal solutions is polynomially bounded for polynomial objective functions.

Kai Płociennik, Fraunhofer ITWM

A probabilistic PTAS for shortest common superstring

We consider approximation algorithms for the shortest common superstring problem (SCS). It is well-known that there is a constant $f > 1$ such that there is no efficient approximation algorithm for SCS achieving a factor of at most f in the worst case, unless P=NP. We study SCS on random inputs and present an approximation scheme that achieves, for every $\epsilon > 0$, a $1 + \epsilon$ -approximation in expected polynomial time. This result applies not only if the letters are chosen independently at random, but also to the more realistic mixing model, which allows for dependencies among the letters of the random strings. Our result is based on a sharp tail bound on the optimal compression, which improves a previous result by Frieze and Szpankowski.

Complementarity & variational inequalities

Thu.1.MA 313

Bilevel programs and MPECs

Organizer/Chair Jane Ye, University of Victoria · Invited Session

Chao Ding, National University of Singapore (with Defeng Sun, Jane Ye)

First order optimality conditions for mathematical programs with semidefinite cone complementarity constraints

In this talk we consider a mathematical program with semidefinite cone complementarity constraints (SDCMPCC). Such a problem is a ma-

trix analogue of the mathematical program with (vector) complementarity constraints (MPCC) and includes MPCC as a special case. We derive explicit expressions for the strong-, Mordukhovich- and Clarke- (S-, M- and C-)stationary conditions and give constraint qualifications under which a local solution of SDCMPCC is a S-, M- and C-stationary point.

Stephan Dempe, TU Bergakademie Freiberg (with Alain Zemkoho)

Optimality conditions for bilevel programming problems

Bilevel programming problems are hierarchical optimization problems where the feasible region is (in part) restricted to the graph of the solution set mapping of a second parametric optimization problem. To solve them and to derive optimality conditions for these problems this parametric optimization problem needs to be replaced with its (necessary) optimality conditions. This results in a (one-level) optimization problem. In the talk different approaches to transform the bilevel programming will be suggested, and relations between the original bilevel problem and the one replacing it will be investigated. Necessary optimality conditions being based on these transformations will be formulated.

Jane Ye, University of Victoria (with Guihua Lin, Mengwei Xu)

On solving bilevel programs with a nonconvex lower level program

By using the value function of the lower level program, we reformulate a simple bilevel program where the lower level program is a nonconvex minimization problem with a convex set constraint as a single level optimization problem with a nonsmooth inequality constraint and a convex set constraint. To deal with such a nonsmooth and nonconvex optimization problem, we design a smoothing projected gradient algorithm for a general optimization problem with a nonsmooth inequality constraint and a convex set constraint. We show that, if either the sequence of the penalty parameters is bounded or the extended Mangasarian-Fromovitz constraint qualification holds at the accumulation point of the iteration points, any accumulation point is a stationary point of the nonsmooth optimization problem. We apply the smoothing projected gradient algorithm to the bilevel program if the calmness condition holds and to an approximate bilevel program otherwise.

Conic programming

Thu.1.H 2036

Linear programming: Theory and algorithms

Chair Tomonari Kitahara, Tokyo Institute of Technology

Andre Tits, University of Maryland, College Park (with Pierre-Antoine Absil, Meiyun He, Ming-Tse Laiu, Dianne O'Leary, Sungwoo Park, Luke Winternitz)

The power of constraint reduction in interior-point methods

Constraint reduction is a technique by which, within an interior-point method, each search direction is computed based only on a small subset of the inequality constraints, containing those deemed most likely to be active at the solution. A dramatic reduction in computing time may result for severely imbalanced problems, such as fine discretizations of semi-infinite problems.

In this talk, we survey recent advances by the authors, including an algorithm with polynomial complexity. The power of constraint reduction is demonstrated on real-world applications, including filter design. Numerical comparison with both simplex and "unreduced" interior point is reported.

Barbara Abdessamad, IMB Université de Bourgogne

Strict quasi-concavity and the differential barrier property of gauges in linear programming

Concave gauge functions were introduced to give an analytical representation to cones. In particular, they give a simple and a practical representation of the positive orthant. The purpose of the present paper is to present another approach to penalizing the positivity constraints of a linear program by using an arbitrary strictly quasi-concave gauge representation. Throughout the paper, we generalize the concept of the central path and the analytic center in terms of these gauges, introduce the differential barrier concept and establish its relationship with strict quasi-concavity.

Tomonari Kitahara, Tokyo Institute of Technology (with Shinji Mizuno)

A proof by the simplex method for the diameter of a (0,1)-polytope

Naddef (1989) showed that the Hirsch conjecture is true for (0,1)-polytopes by proving that the diameter of any (0,1)-polytope in d -dimensional Euclidean space is at most d . In this short paper, we give a simple proof for the diameter. The proof is based on the number of solutions generated by the simplex method for a linear programming problem. Our work is motivated by Kitahara and Mizuno (2011), in which they got upper bounds for the number of different solutions generated by the simplex method.

Conic programming**Thu.1.H 2038****New results in copositive and semidefinite optimization**

Organizer/Chair Mirjam Dür, University of Trier · Invited Session

Luuk Gijben, Rijksuniversiteit Groningen (with Peter Dickinson, Mirjam Dür, Roland Hildebrand)

Scaling relationship between the copositive cone and Parrilo's first level approximation

Several NP-complete problems can be turned into convex problems by formulating them as optimization problems over the copositive cone. Unfortunately checking membership in the copositive cone is a co-NP-complete problem in itself. To deal with this problem, several approximation schemes have been developed. One of them is the hierarchy of cones introduced by P. Parrilo, membership of which can be checked via semidefinite programming. We know that for matrices of order $n \leq 4$ the zero order parillo cone equals the copositive cone. In this talk we will investigate the relation between the hierarchy and the copositive cone for order $n > 4$. In particular a surprising result is found for the case $n = 5$.

Faizan Ahmed, University of Twente (with Georg Still)

On connections between copositive programming and semi-infinite programming

In this presentation we will discuss about the connections between copositive programming (CP) and Linear Semi-infinite Programming (LSIP). We will view copositive programming as a special instance of linear semi-infinite programming. Discretization methods are well known for solving LSIP (approximately). The connection between CP and LSIP will lead us to interpret certain approximation schemes for CP as a special instance of discretization methods for LSIP. We will provide an overview of error bound for these approximation schemes in terms of the mesh size. Examples will illustrate the structure of the programs.

Bolor Jargalsaikhan, University of Groningen (with Mirjam Dür, Georg Still)

Conic programming: Genericity results and order of minimizers

We consider generic properties of conic programs like SDPs and copositive programs. In this context, a property is called generic, if it holds for "almost all" problem instances. Genericity of properties like non-degeneracy and strict complementarity of solutions has been studied. In this talk, we discuss genericity of Slater's condition in conic programs, in particular for SDP and copositive programs. We also discuss the order of the minimizers in SDP and copositive problems, which has important consequences for the convergence rate in discretization methods.

Constraint programming**Thu.1.H 3003A****Instance-specific tuning, selection, and scheduling of solvers**

Organizer/Chair Meinolf Sellmann, IBM Research · Invited Session

Meinolf Sellmann, IBM Research (with Yuri Malitsky, Ashish Sabrahwal, Horst Samulowitz)

Solver portfolios

We discuss the idea of selecting and scheduling solvers based on the features of a given input instance. In particular, we review the recently proposed SAT Solver Selector (3S) and its parallel counterpart, p3S.

Yuri Malitsky, University College Cork (with Meinolf Sellmann)

Instance-specific algorithm configuration

The presentation focuses on a method for instance-specific algorithm configuration (ISAC). ISAC is a general configurator that focuses on tuning different categories of parameterized solvers according to the instances they will be applied to. Specifically, this presentation will show that the instances of many problems can be decomposed into a representative vector of features. It will further show that instances with similar features often cause similar behavior in the applied algorithm. ISAC exploits this observation by automatically detecting the different sub-types of a problem and then training a solver for each variety. This technique is explored on a number of problem domains, including set covering, mixed integer, satisfiability, and set partitioning. ISAC is then further expanded to demonstrate its application to traditional algorithm portfolios and adaptive search methodologies. In all cases, marked improvements are shown over the existing state-of-the-art solvers.

Lin Xu, University of British Columbia (with Holger Hoos, Frank Hutter, Kevin Leyton-Brown)

Evaluating component solver contributions to portfolio-based algorithm selectors

Portfolio-based algorithm selection can exploit complementary strengths of different solvers and often represent the state of the art for solving many computationally challenging problems. In this work, we argue that a state-of-the-art method for constructing such algorithm selectors for the propositional satisfiability problem (SAT), SATzilla,

also gives rise to an automated method for quantifying the importance of each of a set of available solvers. We entered the latest version of SATzilla into the analysis track of the 2011 SAT competition and draw two main conclusions from the results that we obtained. First, automatically-constructed portfolios of sequential, non-portfolio competition entries perform substantially better than the winners of all three sequential categories. Second, and more importantly, a detailed analysis of these portfolios yields valuable insights into the nature of successful solver designs in the different categories. For example, we show that the solvers contributing most to SATzilla were often not the overall best-performing solvers, but instead solvers that exploit novel solution strategies to solve instances that would remain unsolved without them.

Finance & economics**Thu.1.H 3027****Risk management in financial markets**

Organizers/Chairs Nikos Trichakis, Harvard Business School; Dan Iancu, Stanford University · Invited Session

Gerry Tsoukalas, Stanford University (with Kay Giesecke, Jiang Wang)

Dynamic portfolio execution

We analyze the problem of dynamic portfolio execution for a portfolio manager facing adverse market impact and correlated assets. We focus on the market microstructure and show that supply/demand information, contained in the assets' limit order books, can be utilized to improve execution efficiency. Adopting a partial-equilibrium framework, we show that the multivariate problem requires an extended liquidity model which cannot be efficiently solved via the usual dynamic programming methods. We provide an equivalent static reformulation of the problem that is solvable in polynomial time. We find that a strategic manager can take advantage of asset cross-elasticities to mitigate adverse market impact and significantly reduce risk-adjusted execution costs. We also introduce and analyze an important trade-off that arises in heterogeneous portfolios, between the manager's need to minimize costs, and his desire to remain well-diversified throughout the horizon. We develop a simple risk management tool which gives managers dynamic control over this trade-off.

Zachary Feinstein, Princeton University (with Birgit Rudloff)

Set-valued dynamic risk measures

Set-valued risk measures appear naturally when markets with transaction costs are considered and capital requirements can be made in a basket of currencies or assets. We discuss the definition for such functions and the financial interpretation. Results for primal and dual representations of set-valued dynamic risk measures are deduced. Definitions of different time consistency properties in the set-valued framework are given. It is shown that in the set-valued case the recursive form for multivariate risk measures as well as an additive property for the acceptance sets is equivalent to a stronger time consistency property called multi-portfolio time consistency. As an example we consider the superhedging problem in markets with proportional transaction costs.

Vishal Gupta, Massachusetts Institute of Technology (with Dimitris Bertsimas)

A data-driven approach to risk preferences

Accurately specifying risk preferences is critical to financial applications; yet, risk preferences are not directly observable. Typical industry practice asks investors to self-describe as "conservative" or "risky". In this work we take a data-driven perspective. Using ideas from inverse optimization, we construct risk measures that are consistent with an investor's historical portfolio holdings. When applied to a single investor's portfolio, our technique recovers a coherent risk measure approximately describing her behavior. This risk measure can then be used to inform subsequent reallocation or to cluster similar investors. When applied to the market portfolio, our approach provides an alternative derivation of the popular Black-Litterman estimator. Unlike the original Bayesian derivation, our approach requires no probabilistic assumptions, and generalizes beyond the mean-variance paradigm. Indeed, we propose "BL"-type estimators in environments characterized by volatility uncertainty. Computational experience suggests portfolios built from these estimators offer a better risk-reward tradeoff than their traditional counterparts.

Game theory

Thu.1.MA 005

Mechanisms for resource allocation problems

Organizer/Chair Giorgos Christodoulou, University of Liverpool · Invited Session

Carmine Ventre, University of Teesside (with Paul Goldberg)

Using lotteries to approximate the optimal revenue

There has been much recent work on the revenue-raising properties of truthful mechanisms for selling goods. Typically the revenue of a mechanism is compared against a benchmark (such as, the maximum revenue obtainable by an omniscient seller selling at a fixed price to at least two customers), with a view to understanding how much lower the mechanism's revenue is than the benchmark, in the worst case. Here we study this issue in the context of *lotteries*, where the seller may sell a probability of winning an item. We are interested in two general issues. Firstly, we aim at using the true optimum revenue as benchmark for our auctions. Secondly, we study the extent to which the additional expressive power resulting from lotteries, helps to improve the worst-case ratio.

We study this in the well-known context of digital goods, where the production cost is zero. We show that in this scenario, collusion-resistant lotteries (these are lotteries for which no coalition of bidders exchanging side payments has an advantage in lying) are as powerful as truthful ones.

Vangelis Markakis, Athens University of Economics and Business (with Christos-Alexandros Psomas)

On worst-case allocations in the presence of indivisible goods

We study a fair division problem with indivisible goods. In such settings, proportional allocations do not always exist, i.e., allocations where every agent receives a bundle of goods worth to him at least $1/n$, with n being the number of agents. Hence one would like to find worst case guarantees on the value that every agent can have. We focus on algorithmic and mechanism design aspects of this problem. In the work of [Hill 1987], an explicit function was identified, such that for any instance, there exists an allocation that provides at least this guarantee to everybody. The proof however did not imply an efficient algorithm for finding such allocations. Following upon the work of Hill, we first provide a slight strengthening of the guarantee we can make for every agent, as well as a polynomial time algorithm for computing such allocations. We then move to the design of truthful mechanisms. For deterministic mechanisms, we obtain a negative result showing that a truthful $2/3$ -approximation of this guarantee is impossible. We complement this with a constant approximation for a constant number of goods. Finally we also establish some negative results for randomized algorithms.

Annamaria Kovacs, Goethe University, Frankfurt/M. (with Giorgos Christodoulou)

Characterizing anonymous scheduling mechanisms for two tasks

We study truthful mechanisms for domains with additive valuations, like scheduling mechanisms on unrelated machines, or additive combinatorial auctions. Providing a global, Roberts-like characterization of such mechanisms is a classic, long open problem. Among others, such a characterization could yield a definitive bound on the makespan approximation ratio of truthful scheduling.

We investigate special classes of allocation functions, and show that any allocation that is either locally efficient (envy-free) or anonymous ('player-symmetric') must be a special affine minimizer, i.e. a weighted version of the VCG allocation. This is the first characterization result for truthful unrelated scheduling on more than two machines.

Interestingly, for the 'mirrored' problem of additive combinatorial auctions our characterization admits mechanisms different from affine minimizers. Thus our result demonstrates the inherent difference between the scheduling and the auctions domain, and inspires new questions related to truthfulness in additive domains.

Game theory

Thu.1.MA 043

Mean-field approaches to large scale dynamic auctions and mechanisms

Organizers/Chairs Gabriel Weintraub, Columbia Business School; Santiago Balseiro, Columbia University · Invited Session

Krishnamurthy Iyer, Stanford University (with Ramesh Johari, Mukund Sundararajan)

Mean field equilibria of dynamic auctions with learning

We study learning in a dynamic setting where identical copies of a good are sold over time through a sequence of second price auctions. Each agent in the market has an *unknown* independent private valuation which determines the distribution of the reward she obtains from the good; for example, in sponsored search settings, advertisers may initially be unsure of the value of a click. Though the induced dynamic game is complex, we simplify analysis of the market using an approximation

methodology known as *mean field equilibrium* (MFE). The methodology assumes that agents optimize only with respect to long run average estimates of the distribution of other players' bids. We show a remarkable fact: in a mean field equilibrium, the agent has an optimal strategy where she bids truthfully according to a *conjoint valuation*. The conjoint valuation is the sum of her current expected valuation, together with an overbid amount that is exactly the expected marginal benefit to one additional observation about her true private valuation. We conclude by establishing a dynamic version of the revenue equivalence theorem.

Santiago Balseiro, Columbia University (with Omar Besbes, Gabriel Weintraub)

Auctions for online display advertising exchanges: Approximations and design

We study the competitive landscape that arises in Ad Exchanges and the implications for publishers' decisions. Advertisers join these markets with a pre-specified budget and participate in multiple auctions over the length of a campaign. They bid on online ad placements based on specific viewer information. We introduce the notion of a Fluid Mean Field Equilibrium (FMFE) to study the advertisers' dynamic bidding strategies. This concept is based on a mean field approximation to relax the informational requirements of advertisers, together with a fluid approximation to approximate the complex dynamics of the advertisers' stochastic control problems. We derive a closed-form characterization of the bidding strategies under a FMFE, and of the resulting landscape. Using this characterization, we study the auction design problem from the publisher's perspective, and analyze the impact of three design levers: (1) the reserve price; (2) the supply of impressions to the Exchange versus an alternative channel; and (3) the disclosure of viewers' information. Our results provide novel insights with regard to the description and design of such markets.

Alexandre Proutiere, KTH (with Ramki Gummadi, Peter Key)

Optimal bidding strategies and equilibria in repeated auctions with budget constraints

How should agents bid in repeated sequential auctions when they are budget constrained? A motivating example is that of sponsored search auctions, where advertisers bid in a sequence of generalized second price (GSP) auctions. These auctions have many idiosyncratic features that distinguish them from other models of sequential auctions. (1) Each bidder competes in a large number of auctions, where each auction is worth very little. (2) The total bidder population is large, which means it is unrealistic to assume that the bidders could possibly optimize their strategy by modeling specific opponents. (3) The presence of a virtually unlimited supply of these auctions means bidders are necessarily expense constrained. Motivated by these three factors, we first frame the generic problem as a discounted Markov Decision Process and provide a structural characterization of the associated value function and the optimal bidding strategy, which specifies the extent to which agents underbid from their true valuation due to budget constraints. We then show the existence of Mean Field Equilibria for both the repeated second price and GSP auctions with a large number of bidders.

Global optimization

Thu.1.H 2053

Advances in global optimization I

Chair Pál Burai, TU Berlin and University of Debrecen

Dmytro Leshchenko, Odessa State Academy of Civil Engineering and Architecture (with Leonid Akulenko, Alla Rachinskaya, Yanina Zinkevich)

Optimal deceleration of an asymmetric gyrostat in a resistive medium

We investigate the problem of time-optimal deceleration of rotations of a dynamically asymmetric body with a spherical cavity filled with highly viscous fluid (for small Reynolds numbers). In addition, the rigid body is subjected to the action of a small retarding torque of linear resistance of the medium. The rotations are controlled by a bounded torque, which can be exerted by vernier jet engines. The functional Schwartz inequality turns out very useful in synthesizing control laws for deceleration of quasi-rigid bodies. Approximate solutions of perturbed minimum-time problems on rotation deceleration of rigid bodies relative to the center of mass, including objects with internal degrees of freedom, which have applications in dynamics of space- and aircrafts, are obtained. A number of mechanical models are invariant with respect to the angular momentum. In our problem the asymptotic approach made is possible to determine the control, time (Bellman's function), evolutions of the magnitude of the elliptic functions modulus, and dimensionless kinetic energy and kinetic moment. The qualitative properties of the optimal motion were found.

Emilio Carrizosa, Universidad de Sevilla (with Rafael Blanquero, Amaya Nogales)

Location on networks. Global optimization problems

We address some low-dimensional location problems on networks.

Contrary to classical location models such as the p -median or p -center, for which finite dominating sets exist, we consider models (e.g., the Huff problem, the p -median problem with continuously distributed demand) which can be written as (piecewise) d.c. optimization problems.

Structural properties are analyzed, and a branch-and-bound algorithm which exploits the d.c. structure of the objective to obtain bounds is described. Computational results are given, showing that problems on large networks are solvable in reasonable time as soon the number of facilities is small.

Pál Burai, TU Berlin and University of Debrecen

Necessary and sufficient condition on global optimality without convexity and second order differentiability

The main goal of this talk is to give a necessary and sufficient condition of global optimality for unconstrained optimization problems, when the objective function is not necessarily convex. We use Gâteaux differentiability of the objective function and its bidual (the latter is known from convex analysis).

Implementations & software

Thu.1.H 0110

Commercial mathematical programming solvers II

Organizer/Chair Hans Mittelmann, Arizona State University · Invited Session

Hans Mittelmann, Arizona State University

Selected benchmarks in continuous and discrete optimization

From our benchmarks at <http://plato.asu.edu/bench.html> we will quote the discrete and some of the continuous benchmarks. The discrete benchmarks are partly based on MIPLIB 2010. The continuous benchmarks include LP/QP, QCQP, SOCP, and SDP.

Joachim Dahl, MOSEK ApS

Extending the conic optimizer in MOSEK with semidefinite cones

We discuss the conic optimizer in MOSEK with a special emphasis on the recent semidefinite capabilities in the solver.

Robert Bixby, Gurobi Optimization, Inc. (with Zonghao Gu, Ed Rothberg)

Presolve for linear and mixed-integer programming

For linear programming, presolve typically amounts to reducing the size of the model; however, for mixed-integer programming the changes can be much more fundamental, producing a model "strengthening", where this strengthening doesn't simply speed the solution process, but can be the difference between a model being solvable and hopeless. We will examine the effect of presolve, including the effects of some of the key reductions as well as some of the more interesting new reductions that have been discovered over the last several years.

Implementations & software

Thu.1.H 1058

Modeling languages and software I

Organizer/Chair Robert Fourer, AMPL Optimization · Invited Session

John Sirola, Sandia National Laboratories (with William Hart, Jean-Paul Watson)

Modeling and optimizing block-composable mathematical programs in Pyomo

Computational tools for modeling mathematical programs are in wide-spread use within both academia and industry. However, available commercial and open-source software packages broadly lack capabilities for specifying, manipulating, and solving hierarchically structured mathematical programs, e.g., in which sub-blocks of variables and constraints are manipulated and composed to form a more complex, higher-level optimization model (ASCEND [<http://www.ascend4.org>] and JModelica.org [<https://www.jmodelica.org>] are notable exceptions). Our experience with real-world optimization applications indicates that this modeling capability is critical, in methodological contexts ranging from stochastic programming to generalized disjunctive programming, and in application contexts such as electrical grid operations and planning problems. In this talk, we discuss mechanisms for expressing, manipulating, and solving hierarchically or block structured mathematical programs available in the Pyomo open-source Python modeling environment and distributed as part of the broader Coop project for optimization. We motivate the need for this capability using a variety of illustrative examples.

Guillaume Sagnol, Zuse Institut Berlin (ZIB)

PICOS: A python interface to conic optimization solvers

PICOS is a new user-friendly modeling language written in python, which interfaces several conic and integer programming solvers, similarly to YALMIP under MATLAB. PICOS offers the possibility to enter an

optimization problem as a high level model, and to solve it with several different solvers. This can be very useful to quickly implement some models and test their validity on simple examples. Furthermore, with PICOS one can take advantage of the python programming language to easily read and write data, construct a list of constraints by using list comprehensions, take slices of multidimensional variables, ...

In this talk, I will give a tutorial on PICOS, showing how to enter different optimization problems such as linear programs (LP), mixed integer programs (MIP), second order cone programs (SOCP), semidefinite programs (SDP), quadratically constrained quadratic programs (QCQP) or geometric programs (GP) in PICOS, and how to solve these problems with several solvers, including cvxopt, scip, mosek and cplex.

Robert Fourer, AMPL Optimization (with Jared Erickson)

Strategies for using algebraic modeling languages to formulate second-order cone programs

A surprising variety of optimization applications can be written as convex quadratic problems that linear solvers can be extended to handle effectively. Particular interest has focused on conic constraint regions and the "second-order cone programs" (or SOCPs) that they define. Whether given quadratic constraints define a convex cone can in principle be determined numerically, but of greater interest are the varied combinations of sums and maxima of Euclidean norms, quadratic-linear ratios, products of powers, p -norms, and log-Chebyshev terms that can be identified and transformed symbolically. The power and convenience of algebraic modeling language may be extended to support such forms, with the help of a recursive tree-walk approach that detects and converts arbitrarily complex instances – freeing modelers from the time-consuming and error-prone work of maintaining the equivalent SOCPs explicitly. These facilities moreover integrate well with other common linear and quadratic transformations. We describe the challenges of creating the requisite detection and transformation routines, and report computational tests using the AMPL language.

Integer & mixed-integer programming

Thu.1.H 2013

Polyhedral combinatorics

Chair Vinicius Forte, Universidade Federal do Rio de Janeiro

Diego Delle Donne, Universidad Nacional de General Sarmiento (with Javier Marenco)

Vertex coloring polytopes over trees and block graphs

Many variants of the vertex coloring problem have been defined, such as *precoloring extension*, μ -coloring, (γ, μ) -coloring, and *list coloring*. These problems are NP-hard, as they generalize the classical vertex coloring problem. On the other side, there exist several families of graphs for which some of these problems can be solved in polynomial time. The standard integer programming model for coloring problems uses a binary variable x_{vc} for each vertex v and each color c to indicate whether v is assigned c or not. An extension of this model considers binary variables w_c for each color c to indicate whether color c is used or not. In this work we study this formulation for the polynomial cases of the coloring problems mentioned above. In particular, we prove that if the classical vertex coloring problem yields an integer polytope for a family of graphs, then the same holds for μ -coloring, (γ, μ) -coloring, and list coloring over the same family. We prove that the polytope associated to these problems over trees is integer, and we provide empirical evidence suggesting that the same holds for block graphs.

Vinicius Forte, Universidade Federal do Rio de Janeiro (with Abilio Lucena, Nelson Maculan)

Formulations and exact solution algorithms for the minimum two-connected dominating set problem

Given an undirected graph $G = (V, E)$ a dominating set is a subset D of V such that any vertex of V is in D or has a neighbor vertex in D . The dominating set is 2-connected if the subgraph $G(D)$, it induces in G , is 2-connected and the Minimum 2-Connected Dominating Set Problem (M2CDS) asks for a least cardinality 2-connected D . The problem has applications in the design of ad-hoc wireless telecommunication networks. However no exact solution algorithm or heuristic appears to exist for it in the literature. In this presentation we discuss a number of different formulations for the M2CDS as well as some valid inequalities to strengthen them. The formulations address the two variants of the problem, namely the 2-edge connected and the 2-node connected ones and are based on either cut-set inequalities or multi-commodity flows. Preliminary computational results are discussed for branch and cut algorithms based on these formulations.

Mónica Braga, Universidad Nacional de General Sarmiento (with Javier Marenco)

The acyclic coloring polytope

A coloring of a graph G is an assignment of colors to the vertices of G such that any two vertices receive distinct colors whenever they are adjacent. An *acyclic coloring* of G is a coloring such that no cycle of G

receives exactly two colors, and the *acyclic chromatic number* $\chi_A(G)$ of a graph G is the minimum number of colors in any such coloring of G . Given a graph G and an integer k , determining whether $\chi_A(G) \leq k$ or not is NP-complete even for $k = 3$. The acyclic coloring problem arises in the context of efficient computations of sparse and symmetric Hessian matrices via substitution methods. In this work we present an integer programming approach for this problem, by introducing a natural integer programming formulation and presenting six facet-inducing families of valid inequalities. We study the disjunctive rank of these families of valid inequalities for the polytope associated to this formulation. We also introduce the concept of disjunctive anti-rank and study the anti-rank of these families.

Integer & mixed-integer programming

Thu.1.H 2032

Branch-and-price II: Column and row generation

Organizer/Chair Marco Lübbecke, RWTH Aachen University · Invited Session

Pedro Munari, University of Sao Paulo (with Jacek Gondzio)

Using interior point methods in branch-price-and-cut framework

Branch-price-and-cut framework has proven to be a very powerful method for solving integer programming problems. It combines decomposition techniques with the generation of both columns and valid inequalities and relies on strong bounds to guide the search in the branch-and-bound tree. In this talk, we present how the performance of branch-price-and-cut framework can be improved by using the primal-dual interior point method. We discuss in detail how the challenges involved in combining the primal dual interior point method with the integer programming techniques are addressed. The effort to overcome the difficulties pays off in a number of advantageous features offered by the new approach. We present the computational results of solving the well-known instances of the Vehicle Routing Problem with Time Windows, a challenging integer programming problem. The results confirm that the proposed approach delivers the best overall performance when compared with other branch-price-and-cut frameworks available in the literature.

Kerem Bulbul, Sabanci University (with S. Ilker Birbil, Ibrahim Muter)

Simultaneous column-and-row generation for large-scale linear programs with column-dependent-rows

We develop a simultaneous column-and-row generation algorithm that could be applied to a general class of large-scale linear programming (LP) problems. These problems typically arise in the context of LP formulations with exponentially many variables. The defining property for these formulations is a set of linking constraints, which are either too many to be included in the formulation directly, or the full set of linking constraints can only be identified, if all variables are generated explicitly. Due to this dependence between columns and rows, we refer to this class of LPs as problems with column-dependent-rows. To solve these problems efficiently, we need to be able to generate both columns and rows on-the-fly. We emphasize that the generated rows are structural constraints and distinguish our work from the branch-and-cut-and-price framework. We first characterize the underlying assumptions for the proposed column-and-row generation algorithm. We then introduce in detail a set of pricing subproblems, and prove the optimality of the algorithm. We conclude by applying the proposed framework to the multi-stage cutting stock and the quadratic set covering problems.

Rustan Sadykov, INRIA Bordeaux - Sud-Ouest (with François Vanderbeck)

Column generation for extended formulations

Working in an extended variable space allows one to develop tight reformulations for mixed integer programs. However, a direct treatment by a MIP solver is not possible because of the size of the reformulation. If the extended formulation stems from a decomposition principle: a sub-problem admits an extended formulation from which is derived the extended formulation for the original problem, then, one can implement column generation for this extended formulation by transposing the equivalent procedure for the Dantzig-Wolfe reformulation. Pricing sub-problem solutions are expressed in the variables of the extended formulation and added to the current restricted version of the extended formulation along with the active sub-problem constraints. This so-called "column-and-row generation" procedure is revisited here in an unifying presentation and extended to the case of working with an approximate extended formulations. Numerical comparison of column-and-row generation with standard column generation shows that lifting pricing problem solutions in the space of the extended formulation permits their recombination into new sub-problem solutions and results in faster convergence.

Integer & mixed-integer programming

Thu.1.H 2033

New developments in integer programming

Organizer/Chair Andreas S. Schulz, MIT · Invited Session

Daniel Dadush, Georgia Institute of Technology

Convex minimization over the integers

In the seminal works of Lenstra (MOR '83) and Kannan (MOR '87), it was shown that any n variable Integer Linear Program (ILP) can be solved in time $2^{O(n)} n^{2.5n}$ (with polynomial dependence on the remaining parameters). In this work, we give a $2^{O(n)} n^n$ time algorithm to minimize a convex function over the integer points in any n dimensional convex body, thereby improving the computational complexity of the Integer Programming Problem. The algorithm yields the first exact algorithm for Convex IP and the current fastest algorithm for ILP. For our techniques, we rely on new insights in the geometry of numbers as well as new algorithms for lattice problems.

Guus Regts, CWI (with Dion Gijswijt)

Polyhedra with the integer Carathéodory property

A polyhedron P has the Integer Carathéodory Property if the following holds. For any positive integer k and any integer vector $w \in kP$, there exist affinely independent integer vectors $x_1, \dots, x_t \in P$ and positive integers n_1, \dots, n_t such that $n_1 + \dots + n_t = k$ and $w = n_1 x_1 + \dots + n_t x_t$.

It was shown by Bruns et. al (W. Bruns, J. Gubeladze, M. Henk, A. Martin, R. Weismantel, A counter example to an integer analogue of Carathéodory's theorem, J. Reine Angew. Math., 510 (1999), pp. 179-185) that the Integer Carathéodory Property is strictly stronger than the integer decomposition property.

In this talk I will show that if P is a (poly)matroid base polytope or if P is defined by a totally unimodular matrix, then P has the Integer Carathéodory Property. For the matroid base polytope this answers a question by Cunningham from 1984.

Juliane Dunkel, IBM Research (with Andreas Schulz)

A refined Gomory-Chvátal closure for polytopes in the unit cube

We introduce a natural strengthening of Gomory-Chvátal cutting planes for the important class of 0/1-integer programming problems and study the properties of the elementary closure that arises from the new class of cuts. Most notably, we prove that the new closure is polyhedral, we characterize the family of all facet-defining inequalities, and we compare it to elementary closures associated with other cutting-plane procedures.

Life sciences & healthcare

Thu.1.MA 376

Life sciences and healthcare "à la Clermontoise"

Organizer/Chair Annegret Wagler, University Blaise Pascal (Clermont-Ferrand II)/CNRS · Invited Session

Vincent Barra, Clermont University, Blaise Pascal University, LIMOS - UMR 6158 (with Clément de Ribet, Rune Eikeland, Erik Hanson, Erlend Hodneland, Arvid Lundervold, Tessa Welte)

Assessing functional brain connectivity changes in cognitive aging using RS-fMRI and graph theory

The observation that spontaneous BOLD fMRI activity is not random noise, but is organized in the resting human brain as functionally relevant resting state networks has generated a new avenue in neuroimaging and cognitive research, where brain connectivity and graph theory are increasingly important concepts for understanding and for computation. We investigate functional brain connectivity and graph analysis methodology applied to the aging brain at two quite different time scales. The study involves whole brain BOLD fMRI measurements, conducted at time t_1 and t_2 3 years later, designing binary functional connectivity graphs G_{i1} and G_{i2} for subjects $i = 1, N$. We computed local and global nodal network metrics to assess functional connectivity changes between these graph collections. We found individual and group-wise reduction from t_1 to t_2 in all local and global graph indices. These findings were uniform across different threshold values used for thresholding the Pearson's correlations (edge weights) in order to obtain the binary graphs. Several perspectives are proposed by these preliminary results, eg in the context of test-retest reliability and reproducibility of graph metric.

Engelbert Mephu Nguifo, LIMOS, Clermont University, UBP, CNRS (with Sabeur Aridhi, Mondher Maddouri, Rabie Saidi)

Stability measurement of motif extraction methods from protein sequences in classification tasks

Feature extraction is an unavoidable task, especially in the critical step of pre-processing of biological sequences. This step consists for example in transforming the biological sequences into vectors of motifs where each motif is a subsequence that can be seen as a property

(or attribute) characterizing the sequence. Hence, we obtain an object-property table where objects are sequences and properties are motifs extracted from sequences. This table can be used to apply standard machine learning tools to perform data mining tasks such as classification. Previous works described motif extraction methods for sequences classification, but none of them discussed the robustness of these methods when perturbing the input data. In this work, we introduce the notion of stability of the generated motifs in order to study the robustness of motif extraction methods. We express this robustness in terms of the ability of the method to reveal any change occurring in the input data and also its ability to target the interesting motifs. We use these criteria to evaluate and experimentally compare four existing methods.

Romain Pogorelcnik, LIMOS- CNRS (with Anne Berry, Annegret Wagler)

Clique separator decomposition and applications to biological data

The study of gene interactions is an important research area in biology. Nowadays, high-throughput techniques are available to obtain gene expression data, and clustering is a first mandatory step towards a better understanding of the functional relationships between genes. We propose a new approach using graphs to model this data, and decompose the graphs by means of clique minimal separators. A clique separator is a clique whose removal increases the number of connected components of the graph; the decomposition is obtained by repeatedly copying a clique separator into the components it defines, until only subgraphs with no clique separators are left: these subgraphs will be our clusters. The advantage of our approach is that this decomposition can be computed efficiently, is unique, and yields overlapping clusters. The latter enables us to visualize the data by a meta-graph where two clusters are adjacent if they intersect. In addition, clique separators help to identify special genes, called fusion genes, in sequence similarity networks, in the context of evolutionary history. Our first results applying this approach to transcriptomic data are promising.

Logistics, traffic, and transportation

Thu.1.H 0106

Analysis of decentralized network systems

Organizers/Chairs Ozlem Ergun, Georgia Tech; Luyi Gui, Georgia Institute of Technology · Invited Session

Daniela Saban, Columbia University (with Nicolas Stier-Moses)

The competitive facility location game: Equilibria and relations to the 1-median problem

We consider a competitive facility location problem on a network in which consumers are located on the vertices and wish to connect to the nearest facility. Knowing this, competitive players locate their facilities on vertices that capture the largest-possible market share. The competitive facility location problem was first proposed by Hotelling in 1929, where two ice-cream sellers compete on a mile of beach with demand uniformly distributed among the shore. It is well-known that a generalization of that game on a tree always admits an equilibrium. Furthermore, a location profile is an equilibrium if and only if both players locate their facilities in a 1-median of the tree. In this work, we further explore the relationship between the 1-median problem and the equilibria in competitive facility location games with two players. We generalize the previous result to the class of strongly chordal graphs, which strictly contains trees. In addition, we show that for certain classes of graphs in which an equilibrium does not always exist (such as cycles), if there is an equilibrium, it must satisfy that both players select vertices that solve the 1-median problem.

Luyi Gui, Georgia Institute of Technology (with Ozlem Ergun)

A robustness analysis of a capacity exchange mechanism in multicommodity networks under demand uncertainty

We study the coordination of a decentralized multicommodity network system with individually-owned capacities by designing a capacity exchange mechanism under which capacity is traded according to predetermined unit prices. The goal is to maximize the social efficiency, measured by the total routing revenue, of the flow composed by individual players' selfish routing of their own commodities motivated by the mechanism. A practical challenge to do this arises from uncertainties in demand, as in many cases the mechanism is designed before the demand is revealed. Hence, it is desirable that the capacity exchange mechanism is robust, i.e., it can effectively coordinate the network under all potential demand scenarios using a fixed set of exchange prices. In this paper, we perform the following two studies on the robustness of the capacity exchange mechanism under demand uncertainty. First, we characterize how network structure affects the robustness of the mechanism. Second, we investigate the computational side of designing a robust capacity exchange mechanism in any given network. We propose a

general pricing algorithm and quantify the routing performance under the prices computed.

Douglas Fearing, Harvard Business School (with Ian Kash)

Managing air traffic disruptions through strategic prioritization

In the U.S., air traffic congestion places a tremendous financial burden on airlines, passengers, and the economy as a whole. Outside of capacity increases, there are, broadly, two approaches to address congestion. The first is to manage existing capacity more effectively, while the second is to incentivize airlines to schedule fewer flights. In our work, we show how to accomplish both through *strategic prioritization*, a competitive scheme that allows airlines to make flight priority decisions in advance of operations. When there is a disruption, the specified priorities allow the regulator to ration capacity more effectively. Additionally, making these trade-offs causes more of the congestion-related costs to be internalized by each airline, thus reducing over-scheduling. Specifically, our approach requires airlines to bid for a proportional allocation of a fixed pool of prioritization minutes at each airport. We then modify the existing capacity rationing scheme by treating prioritized flights as if they had been scheduled earlier than their actual time. We demonstrate the benefits of this approach through both simulation and theoretical results.

Mixed-integer nonlinear programming

Thu.1.MA 041

Techniques for convex MINLPs

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Pierre Bonami, CNRS - Aix Marseille Université

On disjunctive cuts for mixed integer convex programs

We study the separation of disjunctive cuts for mixed integer nonlinear programs where the objective is linear and the relations between the decision variables are described by convex functions defining a convex feasible region. Our method can be seen as a practical implementation of the classical lift-and-project technique to the nonlinear case. To derive each cut we use a combination of a nonlinear programming subproblem and a linear outer approximation. One of the main features of the approach is that the nonlinear programming subproblems solved to generate cuts are typically not more complicated than the original continuous relaxation. In particular they do not require the introduction of additional variables and maintain the properties of the nonlinear functions describing the feasible region. We propose several strategies for using the technique and present computational evidence of its practical interest. In particular, the cuts allow us to improve the state of the art branch-and-bound of the solver Bonmin, solving more problems in faster computing times on average.

Ashutosh Mahajan, Argonne National Lab (with Sven Leyffer)

Algorithms for solving convex MINLPs with MINOTAUR

MINOTAUR is an open-source software toolkit for implementing algorithms for mixed-integer nonlinear optimization problems. We will describe the design features of the toolkit and present two new algorithms. The first is a new tree-search algorithm for solving convex MINLPs. Rather than relying on computationally expensive nonlinear solves at every node of the branch-and-bound tree, our algorithm solves a quadratic approximation at every node. We show that the resulting algorithm retains global convergence properties for convex MINLPs, and we present numerical results on a range of test problems. The second is an algorithm for presolving MINLPs. In order to improve the formulation of a MINLP in the presolve, we directly manipulate the computational graph of nonlinear functions. Extensive computational results showing effects of presolving on different algorithms for convex MINLPs are provided using what we call 'extended performance-profiles'. We show improvements of up to two orders of magnitude in running time for some classes of problems.

Andrew Miller, Université Bordeaux 1 (with Hyemin Jeon, Jeff Linderoth)

Valid inequalities for a nonseparable quadratic set

We describe approaches for finding strong valid inequalities for the convex hull of a quadratic mixed integer nonlinear set containing two integer variables that are linked by linear constraints. This study is motivated by the fact that such sets appear can be defined by a convex quadratic program, and therefore strong inequalities for this set may help to strengthen the formulation of the original problem.

A number of the inequalities that we define for this set are nonlinear (specifically conic). The techniques used to define strong inequalities include not only ideas related to perspective reformulations of MINLPs, but also disjunctive and lifting arguments. Initial computational tests will be presented.

Mixed-integer nonlinear programming

Thu.1.MA 042

MINLP theory and algorithms

Organizer/Chair Giacomo Nannicini, Singapore University of Technology and Design · Invited Session

Emiliano Traversi, TU Dortmund (with Christoph Buchheim)

Separable underestimators for quadratic combinatorial optimization

We propose a method to obtain separable underestimators for quadratic combinatorial optimization problems. By exploiting separability we can provide lower bounds by solving an integer linear problem and use them in a branch and bound scheme. This is useful in practice when the underlying linear counterpart is easy to solve. We investigate the tightness of the bounds and their effect on the running time of the algorithm. Computational results are provided concerning the quadratic binary unconstrained problem and the quadratic spanning tree problem.

Stefano Coniglio, Politecnico di Milano (with Francois Margot)

Spatial branch-and-bound for nonconvex Euclidean norm constrained mathematical programs

We are interested in mathematical programs involving Euclidean point-to-hyperplane distances. In particular, we focus on the Euclidean Linear Classification problem (ELC) of finding a hyperplane which best separates two sets of points by minimizing the sum of its Euclidean distance to the points on the wrong side. Given a point $a \in \mathbb{R}^n$ and hyperplane with parameters $(w, \gamma) \in \mathbb{R}^{n+1}$, their distance is $|a^T w - \gamma|$ subject to $w^T w \geq 1$, whose feasible region is the nonconvex complement of the unit ball.

First, we observe that standard spatial branch-and-bound (sBB) methods employ not tight relaxations which yield nontrivial bounds only after many iterations. Then, we propose a novel sBB method where the complement of the unit ball is approximated with the complement P^c of polyhedron P . We represent P^c as a disjunction with a subproblem for each facet of P and, at each sBB iteration, we refine it by adding a new vertex to P which corresponds to the new infeasible solution. Compared to a standard sBB on random ELC instances, our method reduces, on average, the computing time by 36%, the number of tree nodes by 63%, and the tree depth by 55%.

Multi-objective optimization

Thu.1.H 1029

Vector optimization

Organizers/Chairs César Gutiérrez, Universidad de Valladolid; Vicente Novo, UNED · Invited Session

Maria Beatriz Hernández-Jiménez, Universidad Pablo de Olavide (with Manuel Arana-Jiménez, Rafaela Osuna-Gómez, Gabriel Ruiz-Garzón)

Characterization of efficient solutions for non-regular multiobjective problems with inequality-type constraints

For multiobjective problems with inequality-type constraints the necessary conditions for efficient solutions are presented. These conditions are applied when the constraints do not necessarily satisfy any regularity assumptions, and they are based on the concept of 2-regularity introduced by Izmailov. In general, the necessary optimality conditions are not sufficient and the efficient solution set is not the same as the Karush-Kuhn-Tucker points set. So it is necessary to introduce generalized convexity notions. In the multiobjective nonregular case we give the notion of 2-KKT-pseudoinvex-II problems. This new concept of generalized convexity is both necessary and sufficient to guarantee the characterization of all efficient solutions based on the optimality conditions.

César Gutiérrez, Universidad de Valladolid (with Bienvenido Jiménez, Vicente Novo)

Approximation of efficient sets via ε -efficient sets

When a vector optimization problem is solved, usually an approximate solution set is attained. In order to this surrogate optimization process works, the obtained ε -efficiency sets should satisfy certain continuity properties with respect to the solution set. In this talk we show several results from which one can analyze this problem, which are based on a generic ε -efficient concept. Finally, some of these results are applied to a vector optimization problem where the objective mapping is set-valued.

Fabián Flores-Bazán, Universidad de Concepción

Efficiency and ordering variational principles

It is shown that several results on ordering principles (among them the Brezis-Browder and the Ekeland variational ones on partially or quasi ordered spaces) that appear in the literature and have been proved in an independent way, have a common root: efficiency. Existence results of maximal elements for non constant binary relations are also discussed.

Nonlinear programming

Thu.1.H 0107

Linear algebra for optimization

Organizer/Chair Dominique Orban, GERAD and Ecole Polytechnique de Montreal · Invited Session

Martin Stoll, MPI Magdeburg (with John Pearson, Tyrone Rees, Andrew Wathen)

Preconditioning for time-dependent PDE-constrained optimization problems

In this talk, we motivate and test effective preconditioners to be used within a Krylov subspace algorithm for solving a number of saddle point systems, which arise in PDE-constrained optimization problems. We consider a variety of setups for different time-dependent PDEs such as the distributed control problem involving the heat equation, the Neumann boundary control problem subject to the heat equation and a distributed control problem with Stokes equations as the PDE-constraint. Crucial to the performance of our preconditioners in each case is an effective approximation of the Schur complement of the matrix system. In each case, we propose the preconditioning approach and provide numerical results, which demonstrate that our solvers are effective for a range of regularization parameter values, as well as mesh sizes and time-steps.

Santiago Aklé, ICME Stanford University (with Michael Saunders)

Preconditioning for iterative computation of search directions within interior methods for constrained optimization

Our primal-dual interior-point optimizer PDICO has found many applications for optimization problems of the form

$$\min \varphi(x) \text{ st } Ax = b, \quad l \leq x \leq u,$$

in which $\varphi(x)$ is convex and A is a sparse matrix or a linear operator. We focus on the latter case and the need for iterative methods to compute dual search directions from linear systems of the form

$$AD^2A^T \Delta y = r, \quad D \text{ diagonal and positive definite.}$$

Although the systems are positive definite, they do not need to be solved accurately and there is reason to use MINRES rather than CG (see PhD thesis of David Fong [2011]). When the original problem is regularized, the systems can be converted to least-squares problems and there is similar reason to use LSMR rather than LSQR.

Since D becomes increasingly ill-conditioned as the interior method proceeds, there is need for some kind of preconditioning. We examine the partial Cholesky approach of Bellavia, Gondzio and Morini (2011) and explore some alternatives that are better suited to applications in which A is a linear operator.

Dominique Orban, GERAD and Ecole Polytechnique de Montreal (with Chen Greif, Erin Moulding)

Spectral analysis of matrices arising in regularized interior-point methods

Interior-point methods feature prominently in the solution of inequality-constrained optimization problems, and involve the need to solve a sequence of 3×3 block indefinite systems that become increasingly ill-conditioned with the iterations. To solve those systems, it is common practice to perform a block Gaussian elimination, and either solve the resulting reduced 2×2 block indefinite system that has a typical saddle-point form, or further reduce the system to the normal equations and apply a symmetric positive definite solver. In this paper we explore whether the step of reducing the system from a 3×3 block matrix to a 2×2 block matrix necessarily pays off. We use energy estimates to obtain bounds on the eigenvalues of the coefficient matrices, and conclude that, at least in terms of spectral structure, it may be better to keep the matrix in its original unreduced form rather than perform a partial elimination before solving it.

Nonlinear programming

Thu.1.H 0112

Convex nonlinear optimization I

Chair Ganesh Perumal, Infosys Limited / International Institute of Information Technology, Bangalore

Stefan Stefanov, Neofit Rilski South-Western University

Convex separable minimization with box constraints

Consider minimization problems with a convex separable objective function subject to a convex separable inequality constraint of the form "less than or equal to" / linear equality constraint / linear inequality constraint of the form "greater than or equal to", respectively, and bounds on the variables (box constraints). Such problems arise in both theoretical considerations and in practical problems. For the first and the second problem, a necessary and sufficient condition is proved for a feasible solution to be an optimal solution to the respective problem, and a sufficient condition is proved for a feasible solution to be an optimal solution to the third problem. Algorithms of polynomial computational

complexity for solving these three problems are proposed and convergence of algorithms is proved. Some particular problems of the form under consideration as well as numerical results are presented.

Ganesh Perumal, Infosys Limited / International Institute of Information Technology, Bangalore (with G. N. Srinivasa Prasanna)

A decomposition technique for convex optimization problems

In this presentation, we give a decomposition technique that is applicable to general convex optimization problems. The feasible space is divided into small sub-spaces and information about a particular sub-space containing the optimal solution is estimated from the cost function and the constraint set. The properties of such sub-spaces and their existential proof are explained. The complexity of applying this decomposition technique is also discussed.

Nonsmooth optimization

Thu.1.H 1012

Nonsmooth optimization theory

Chair Waltraud Huyer, Universität Wien

Anna-Laura Wickström, Universität Zürich

Generalized derivatives of the projection onto the cone of positive semidefinite matrices

We are interested in sensitivity and stability analysis of solution sets of nonlinear optimization problems under set or cone constraints. A main motivation behind our work is the analysis of semidefinite programs (SDPs). We wish to explore the sensitivity analysis of SDPs with help of generalized derivatives.

In order to study critical points and solutions of SDPs we construct a Kojima kind of locally Lipschitz functions of the Karush-Kuhn-Tucker conditions for C^2 -optimization problems over the space of symmetric matrices. We will study generalized derivatives of this Kojima-function in order to show regularity of our problem. The Kojima-function is the product of a continuously differentiable and a nonsmooth function. The latter contains the projection function onto the cone of positive semidefinite matrices. We shall look at the construction of its Thibault derivatives (strict graphical derivatives). Moreover, we examine the relations between Thibault derivatives and Clarke's generalized Jacobians of these projections.

Alain B. Zemkoho, TU Bergakademie Freiberg

Optimization problems with value function objectives

The family of optimization problems with value function objectives includes the minmax programming problem and the (pessimistic and original optimistic) bilevel optimization problem. In this talk, we would like to discuss necessary optimality conditions for this class of problems while assuming that the functions involved are nonsmooth and the constraints are the very general operator constraints.

Waltraud Huyer, Universität Wien (with Arnold Neumaier)

Minimizing functions containing absolute values of variables

We propose an algorithm for the minimization of the function $f(Ax - b, |x|)$ on a box $x \subseteq \mathbb{R}^n$ with nonempty interior, where $|x|$ denotes the componentwise absolute value, f is a C^2 function, $b \in \mathbb{R}^m$ and $A \in \mathbb{R}^{m \times n}$. Moreover, we assume that gradients and Hessian matrices are available and that the Hessian matrices of f can be represented in the form $G = D + R^T E R$, where D and E are diagonal matrices.

The algorithm MINABS proceeds from a starting point by making coordinate searches, minimizing local quadratic models and checking the optimality conditions. For the minimization of the quadratic models, an algorithm for minimizing a quadratic function of the form

$$q(x) = \gamma + c^T x + \frac{1}{2} (Bx - c)^T F (Bx - c),$$

F a diagonal matrix, is developed.

Finally, MINABS is applied to problems of the above kind in order to demonstrate the applicability of the algorithm.

Optimization in energy systems

Thu.1.MA 549

Capacity of gas transport networks

Organizer/Chair Thorsten Koch, ZIB · Invited Session

Christine Hayn, FAU Erlangen-Nürnberg, Discrete Optimization (with Lars Schewe)

Optimal allocation of capacities in gas networks

Due to regulations gas network operators face the new challenge of allocating free capacity at all entry and exit points. Customers may

then book within the reported capacity intervals separately at the entry and exit points. Operators have to guarantee that all expected requests within these intervals (called nominations) can be transported through the network. Where no historical withdrawal data is applicable, the worst-case request situation has to be considered. However, due to gas physics and active elements like compressors, the underlying question whether a nomination can be transported through the network, called nomination validation, already is far from being trivial and is modelled as a non-convex MINLP. Thus, it is not obvious what the operating limits of the network are. We discuss the hardness of the capacity allocation problem and propose an algorithm for solving a relaxed variant. Therein a nomination validation tool is used as black box. The potential of our implementation is demonstrated on real-life instances from gas network optimization.

Lars Schewe, FAU Erlangen-Nürnberg, Discrete Optimization (with Björn Geißler, Alexander Martin, Antonio Morsi)

Mixed-integer-programming methods for gas network optimization

We present methods to formulate and solve MINLPs originating in stationary gas network optimization. To this aim we use a hierarchy of MIP-relaxations. With this hierarchy we are able to give tight relaxations of the underlying MINLP. The methods we present can be generalized to other non-linear network optimization problems with binary decisions. We give computational results for a number of real world instances. The underlying optimization problem can be adapted to give operating limits for the network in fixed scenarios. These results can be used as the basic building block for further study of the allocation of capacities in the network.

Benjamin Hiller, Zuse Institute Berlin (with Hernan Leovey, Andris Möller, Werner Römisich)

An automated method for the booking validation problem

We propose an automated approach to solve the booking validation problem faced by gas network operators: Given a set of transmission capacity contracts (a booking), check whether all balanced gas flows that may result from those contracts are technically realizable. Our approach is based on MINLP methods for checking gas flow realizability complemented by a method for generating a representative subset of the gas flows that may arise. This generation method combines a stochastic model for gas offtakes and a deterministic model for the contractual limitations of both injections and offtakes.

Optimization in energy systems

Thu.1.MA 550

Gas and electricity networks

Organizer/Chair Alexander Martin, FAU Erlangen-Nürnberg · Invited Session

Robert Schwarz, Zuse Institute Berlin

Gas network design with integrated optimization of topology and dimensioning

Natural gas is transported through networks of pipelines from sources to sinks. Given the geographical locations of these points together with nominated amounts of flow, we solve the problem of building the cost-optimal network able to satisfy all demands within the feasible pressure bounds. The decisions include both the selection of arcs where pipelines are built, as well as the choice of suitable diameters out of a set of discrete values with associated cost factors. Because of the nonconvex, nonlinear relationship between the flow rate and the pressure loss along the pipes, the diameters do not correspond directly to flow capacities. This leads to a MINLP formulation of the problem, which is solved using outer approximation and spatial branching. The discrete diameter choice is exploited to reformulate certain subproblems as MILPs after variable fixations during the branch and bound process. We present some preliminary computational results and discuss some possible extensions of the model.

Paul Trodden, University of Edinburgh (with Waqqas Bukhsh, Andreas Grothey, Ken McKinnon)

MILP-based islanding of large electricity networks using an aggregated model of power flows

Wide-area blackout of an electricity network can be prevented by splitting the system into islands. To achieve balanced, feasible islands, nonlinear AC power flow equations should be included, resulting in an MINLP problem. However, for large networks, it is not always necessary to model in detail power flows in areas far from the splitting boundaries. In this talk, we present a MILP-based formulation for islanding that uses an aggregated model of power flows, modelling power flows close to splitting boundaries by a piecewise linear approximated AC model, beyond that a linear DC model, and neglecting individual line flows in areas

far from the boundaries. The effectiveness of the approach is demonstrated by examples of islanding large, real networks.

Ken McKinnon, Edinburgh University (with Waqqas Bukhsh, Andreas Grothey, Paul Trodden)

An MINLP approach to islanding electricity networks

Intentional islanding is attracting an increasing amount of attention as a means of preventing large-scale blackouts in electricity transmission networks. In this talk, a mathematical formulation for islanding is presented, in which suspected unhealthy components of the network are isolated while the load shed is minimized. To achieve balanced, feasible islands, nonlinear AC power flow equations should be included, resulting in an MINLP problem. In the proposed MILP formulation, these terms are approximated by piecewise linear functions. The approach is demonstrated by results on test networks.

PDE-constrained opt. & multi-level/multi-grid meth.

Thu.1.H 0111

PDE optimization in medicine I

Organizer/Chair Anton Schiela, TU Berlin · Invited Session

Luis A. Fernandez, University of Cantabria

Optimizing a chemotherapy model for brain tumors by using PDE

We study some optimal control problems concerning a reaction-diffusion PDE that describes the growth of some brain tumors called gliomas, taking into account the pharmacokinetics of the chemotherapy treatment through its corresponding PDE in different frameworks.

Lars Ole Schwen, Fraunhofer MEVIS (with Preusser Tobias)

Modeling flow through realistic, algorithmically generated vascular structures in the liver

The liver is a highly perfused and central metabolic organ. Its main connection to the rest of the organism is the blood flow through two supplying and one draining vascular system. For modeling blood flow through these, a proper geometric model of the vascular systems in the liver is an important building block.

In vivo imaging or imaging of corrosion casts does not provide sufficient details to obtain a geometric representation of the vascular structures down to the sinusoidal scale. The method of Constrained Constructive Optimization [Buxbaum; Schreiner; Karch et al.] is used for this purpose, determining a structure of minimal intravascular volume that provides homogeneous supply/drainage for the perfused volume.

We quantify the similarity of algorithmically generated vascular structures to real human and murine ones, comparing different geometric features, and use these findings to improve the algorithm. For simulating flow in the whole organ as well as for jointly generating supplying and draining vascular systems, the tissue in between is taken into account as a porous medium in a 3D simulation coupled to the vascular flow.

Lars Lubkoll, Zuse Institute Berlin (with Anton Schiela, Martin Weiser)

Optimal control in implant shape design

As in many parts of modern medicine the design of implants is today more dependent on the experience of medical scientists than on technical tools. Especially in the case of heavy fractures or natural deformations of the oral and maxillofacial bone structure it is often difficult to accurately predict the shape of the patients face after the medical treatment. Consequently it would be of advantage if one could delegate the determination of an implant's shape from a given desired shape of the skin to a computer-assisted tool. This would allow to give reliable assistance regarding the training, preparation and verification of implant insertions. In this context we present an approach that leads to an optimal control problem with an elastic constitutive law as PDE constraint. In the case of linearized elasticity we analyse this problem and will present numerical results. Moreover we will give an outline on our progress on the treatment of more realistic nonlinear material models.

PDE-constrained opt. & multi-level/multi-grid meth.

Thu.1.MA 415

Optimization applications in industry VI

Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics · Invited Session

Ekaterina Kostina, University of Marburg (with H.-G. Bock, G. Kriwet, J.P. Schloeder)

Optimization methods for nonlinear model predictive control of non-stationary partial differential equations

Many spatio-temporal processes in the natural and life sciences, and engineering are described by the mathematical model of non-stationary PDE. It would be of high practical relevance as well as a

mathematical challenge to use such models for a process optimization subject to numerous important inequality restrictions. However in the presence of disturbances and modeling errors the real process will never follow the off-line computed optimal solution. Thus the challenge is to compute feedback controls that take these perturbations into account. We present a new optimization method for the NMPC. The NMPC principle is to solve a complete optimal control problem whenever new information about perturbations is available and to apply the first instant of the optimal control as a feedback law. However the frequency of perturbation information is orders of magnitude higher than even a single optimization iteration. Therefore we discuss multi-level iterations strategy to make NMPC computations real-time feasible for PDE optimal control problems.

Georg Vossen, Niederrhein University of Applied Sciences (with Axel Haeck, Andreas Pittner)

Optimization and model reduction methods for heat source determination in welding

The physical phenomena in welding can yet not completely be described by mathematical models. In industrial applications, it is therefore common to describe the effects of the heat energy by means of a parametrized volume source. Its parameters are obtained in several steps by a calibration of computed and experimental temperature data extracted out of transverse sections and thermo-elements. In each step, a time-dependent partial differential equation (PDE) on a three-dimensional domain has to be solved. The industrial standard practice is to use standard Finite Element methods for simulation of the PDE and to apply the calibration manually leading to overall times of up to several weeks for the procedure.

In this talk, we will formulate the procedure as an optimization problem with a finite-dimensional optimization variable and infinite-dimensional equality constraints, and we will discuss theoretical aspects of the problem. We will then develop and apply optimization strategies combined with model reduction methods such as Proper Orthogonal Decomposition, \mathcal{H}_2 -norm model reduction and Balanced Truncation to solve the problem efficiently.

Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics (with Klaus Krumbiegel, Nataliya Togobytska)

Optimal control of multiphase steel production

In this talk I will discuss an optimal control problem related to the production of multiphase steels. The state system consists of a parabolic equation for the evolution of temperature and a system of rate laws to describe occurring phase transitions, while a coefficient in the Robin boundary condition acts as the control. I will discuss necessary and sufficient optimality conditions, describe a SQP-approach for its numerical solution and conclude with some numerical results for a pilot hot-rolling mill situated in the lab of our partners from engineering sciences at Bergakademie Freiberg.

Robust optimization

Thu.1.MA 004

Robust optimization, estimation and machine learning

Organizer/Chair Aharon Ben-Tal, Technion – Israel Institute of Technology · Invited Session

Shimrit Shtern, Technion – Israel Institute of Technology (with Aharon Ben-Tal)

A robust optimization approach for tracking under bounded uncertainty

Classical dynamic control theory assumes that the system is afflicted with white noise and minimizes estimation mean square estimation error, usually by applying the Kalman filter (KF). In some applications, such as tracking, the assumption of white, unbounded noise is unrealistic. In these cases a worst case analysis, specifically the maximal error norm, might be a better measure of performance. In tracking applications ignoring worst case occurrences might have grave implications, since large errors decrease the probability of successfully tracking an object, especially in presence of clutter or when tracking multiple objects. In order to analyze the worst case scenario for a general dynamic control problem, given the filter, we need to solve a non-convex Quadratic Constrained Quadratic Problem. Since this problem is generally NP-hard we try to utilize the problem's block characteristics in order to find upper and lower bounds. We find these bounds through Semidefinite Programming and Block-wise Optimal Ascent. We compared the KF results to a greedy worst case filter (UBF) and found that, in most cases, UBF indeed performs better in regard to worst case analysis.

Elad Hazan, Technion – Israel Institute of Technology

Sublinear optimization for machine learning

Linear classification is a fundamental problem of machine learning, in which positive and negative examples of a concept are represented in Euclidean space by their feature vectors, and we seek to find a hyperplane separating the two classes of vectors. We'll present the first

sublinear-time algorithms for linear classification, support vector machine training, and other related optimization problems, including general semi-definite programming and robust linear programming. These new algorithms are based on a primal-dual approach, and use a combination of novel sampling techniques and the randomized implementation of online learning algorithms. We give lower bounds which show our running times to be nearly best possible.

Chiranjib Bhattacharyya, Indian Institute of Science (with Aahron Ben-Tal, Sahely Bhadra, Arkadi Nemirovskii)

Making SVM Classifiers robust to uncertainty in kernel matrices

We consider the problem of uncertainty in the entries of the Kernel matrix, arising in Support Vector Machine(SVM) formulation. Using Chance Constraint Programming and a novel large deviation inequality we derive a robust formulation which requires only second order statistics of the uncertainty. The formulation in general is non-convex, but in several cases of interest it reduces to a convex program. To address the non-convexity issue we propose a robust optimization based procedure. Specifically the uncertainty is modeled as a positive affine combination of given positive semi definite kernels, with the coefficients ranging in a norm ∞ -bounded uncertainty set. Subsequently using the Robust Optimization methodology, the SVM problem can be posed as a convex concave saddle point problem. We show that the problem admits an efficient first order algorithm for this problem, which achieves an $O(1/T^2)$ reduction of the initial error after T iterations. A comprehensive empirical study on both synthetic data and real-world protein structure datasets show that the proposed formulations achieve desired robustness.

Sparse optimization & compressed sensing

Thu.1.H 1028

Computable bounds for sparse recovery

Organizer/Chair Anatoli Juditsky, LJK, Université J. Fourier - Invited Session

Alexandre D'Aspremont, CNRS - Ecole Polytechnique

High-dimensional geometry, sparse statistics and optimization

This talk will focus on a geometrical interpretation of recent results in high dimensional statistics and show how some key quantities controlling model selection performance can be approximated using convex relaxation techniques. We will also discuss the limits of performance of these methods and describe a few key open questions.

Fatma Kilinc Karzan, Carnegie Mellon University (with Anatoli Juditsky, Arkadi Nemirovskii)

Verifiable sufficient conditions for ℓ_1 -recovery of sparse signals

In this talk, we will cover some of the recent developments in large-scale optimization motivated by the compressed sensing paradigm. The majority of results in compressed sensing theory rely on the ability to design/use sensing matrices with good recoverability properties, yet there is not much known in terms of how to verify them efficiently. This will be the focus of this talk. We will analyze the usual sparse recovery framework as well as the case when a priori information is given in the form of sign restrictions on the signal. We will propose necessary and sufficient conditions for a sensing matrix to allow for exact ℓ_1 -recovery of sparse signals and utilize them. These conditions, although difficult to evaluate, lead to sufficient conditions that can be efficiently verified via linear or semidefinite programming. We will analyze the properties of these conditions while making connections to disjoint bilinear programming and introducing a new and efficient bounding schema for such programs. We will finish by presenting limits of performance of these conditions and numerical results.

Anatoli Juditsky, LJK, Université J. Fourier (with Fatma Kilinc-Karzan, Arkadi Nemirovskii)

Accuracy guarantees and optimal ℓ_1 -recovery of sparse signals

We discuss new methods for recovery of sparse signals which are based on ℓ_1 minimization. Our emphasis is on verifiable conditions on the problem parameters (sensing matrix and sparsity structure) for accurate signal recovery from noisy observations. In particular, we show how the certificates underlying sufficient conditions of exact recovery in the case without noise are used to provide efficiently computable bounds for the recovery error in different models of imperfect observation. These bounds are then optimized with respect to the parameters of the recovery procedures to construct the estimators with improved statistical properties. To justify the proposed approach we provide oracle inequalities which link the properties of the recovery algorithms to the best estimation performance in the Gaussian observation model.

Stochastic optimization

Thu.1.MA 141

High dimensional statistics: Techniques from stochastic and robust optimization

Organizer/Chair Constantine Caramanis, The University of Texas at Austin - Invited Session

Philippe Rigollet, Princeton University

Deviation optimal model selection using greedy algorithms

A statistical problem of model selection for regression can be simply described as a stochastic optimization problem where the objective is quadratic and the domain finite or countable. To solve this problem it is now known that, contrary to the principle of empirical risk minimization, one should seek a solution in the convex hull of the domain. This idea is implemented by exponential weights that are known to solve the problem in expectation, but they are, surprisingly, sub-optimal in deviation. We propose a new formulation called Q-aggregation that consists in minimizing a penalized version of the original criterion but for which the penalty vanishes at the points of interest. This approach leads to efficient greedy algorithms in the spirit of Frank-Wolfe but for which stronger bounds can be derived.

Shie Mannor, Technion - Israel Institute of Technology (with Constantine Caramanis, Yudong Chen)

Robust sparse regression and orthogonal matching pursuit

In this talk we consider simple, greedy methods for high dimensional regression with noise and erasures. We consider the setting of such corruptions not only in the output variable, but also in the covariates. We show our algorithms are more simple and hence much faster, with excellent empirical performance. We prove bounds on their performance that substantiate our computational results, and in particular show that the guaranteed performance is at least as good as all existing algorithms, including those of greater complexity.

Sujay Sanghavi, UT Austin (with Praneeth Netrapalli)

Learning the graph of network cascades

Cascades, or epidemic processes, are widely used models for phenomena in social networks (for viral marketing, spread of ideas), genetic networks (spread of activation of genes) and epidemiological networks (communicable diseases in populations). We consider the natural inverse problem in this setting: learning the graph of a network, given only node states as the cascade spreads. In this talk we a) Show that for most popular cascade models, this can be posed as a sparse recovery problem in high dimensions, but from non-linear measurements. b) Show that simple maximum likelihood, without regularization but with thresholding, achieves consistent graph recovery with sample complexity close to the corresponding lower bound c) Establish a connection between the network graph, and the Markov graph of the cascade process. We finish with two open problems: the performance of simple greedy algorithms, and the role of correlation decay.

Stochastic optimization

Thu.1.MA 144

Decomposition methods for multistage stochastic programs

Organizer/Chair Vincent Guigues, UFRJ - Invited Session

Vincent Guigues, UFRJ (with Werner Römisch)

Sampling-based decomposition methods for multistage stochastic programs based on extended polyhedral risk measures

We define a risk-averse nonanticipative feasible policy for multistage stochastic programs and propose a methodology to implement it. The approach is based on dynamic programming equations written for a risk-averse formulation of the problem. This formulation relies on a new class of multiperiod risk functionals called extended polyhedral risk measures. Dual representations of such risk functionals are given and used to derive conditions of coherence. In the one-period case, conditions for convexity and consistency with second order stochastic dominance are also provided. The risk-averse dynamic programming equations are specialized considering convex combinations of one-period extended polyhedral risk measures such as spectral risk measures. To implement the proposed policy, the approximation of the risk-averse recourse functions for stochastic linear programs is discussed. In this context, we detail a stochastic dual dynamic programming algorithm which converges to the optimal value of the risk-averse problem.

Wajdi Tekaya, Georgia Institute of Technology (with Joari Da Costa, Alexander Shapiro, Murilo Soares)

Risk neutral and risk averse stochastic dual dynamic programming method

In this talk, we discuss risk neutral and risk averse approaches to multistage linear stochastic programming problems based on the Stochastic Dual Dynamic Programming (SDDP) method. We give a gen-

eral description of the algorithm and present computational studies related to planning of the Brazilian interconnected power system.

Suvrajeet Sen, University of Southern California (with Zhihong Zhou)

Multi-stage stochastic decomposition

In this paper, we propose a statistically motivated sequential sampling method that is applicable to multi-stage stochastic linear programs, and we refer to it as the Multi-stage Stochastic Decomposition (MSD) algorithm. As with earlier SD methods for two-stage stochastic linear programs, this approach preserves one of the most attractive features of SD: asymptotic convergence of the solutions can be proven (with probability one) without any iteration requiring more than a small sample-size. Our asymptotic analysis shows the power of regularization in overcoming some of the assumptions (e.g., independence between stages) associated with other sample-based algorithms for multi-stage stochastic programming.

Telecommunications & networks

Thu.1.H 3002

Networks in production, logistics and transport

Organizer/Chair Sven Krumke, University of Kaiserslautern · Invited Session

Sabine Büttner, University of Kaiserslautern

Online network routing amongst unknown obstacles

We consider variants of online network optimization problems connected to graph exploration. In the prize-collecting travelling salesman problem, we are given a weighted graph $G = (V, E)$ with edge weights $\ell: E \rightarrow \mathbb{R}_+$, a special vertex $r \in V$, penalties $p: V \rightarrow \mathbb{R}_+$ and the goal is to find a closed tour T such that $r \in V(T)$ and such that the cost $\ell(T) + p(V \setminus V(T))$ is minimized. In an online variant, which we call the *Canadian Tour Operator Problem (CTOP)*, the task is to route a tourist bus through a given network $G = (V, E)$ in which some edges are blocked by avalanches. An online algorithm learns from a blocked edge only when reaching one of its endpoints. The bus operator has the option to avoid visiting each node $v \in V$ by paying a refund of $p(v)$ to the tourists. The goal is to minimize the sum of the travel costs and the refunds. We show that no deterministic or randomized algorithm can achieve a bounded competitive ratio for the CTOP on general graphs and give $O(1)$ -competitive algorithms for special networks. We also relate the problem to other (classical) online network and routing problems.

Thomas Werth, TU Kaiserslautern (with Sven Krumke, Heike Sperber)

Bottleneck routing games

We consider Nash and strong equilibria in weighted bottleneck routing games in single commodity networks. In such a game every player chooses a path from the common source vertex to the sink vertex in a graph with directed edges. The cost of an edge depends on the total weight of players choosing it and the personal cost every player tries to minimize is the cost of the most expensive edge in her path, the bottleneck value.

To derive efficient algorithms for finding equilibria in unweighted games, we generalize a transformation of a bottleneck game into a special congestion game introduced by Caragiannis et al. (2005).

For weighted routing games we show that Greedy methods give Nash equilibria in extension-parallel and series-parallel graphs. On the other hand, computing a strong equilibrium is co-NP complete in general graphs, even for linear latency functions.

Furthermore, we show that the Price of Anarchy can be arbitrarily high for different situations and give tight bounds depending on the topology, the number and weights of the users and the degree of the polynomial latency functions.

Marco Bender, University of Göttingen (with Sabine Büttner, Sven Krumke)

Online delay management: Beyond competitive analysis

We consider the Online Delay Management Problem on a network with a path topology that is served by one train. In this problem the number of delayed passengers is not known beforehand but revealed in an online fashion. The goal is to decide at which station a train should wait in order to minimize the total delay of all passengers.

We introduce the concept of a lookahead which yields information about delays at succeeding stations. Although this does not lead to better competitive ratios, we can justify the intuition that it is a feature that does help an algorithm. To this end, we make use of comparative analysis that allows to compare different classes of lookahead algorithms with each other.

Furthermore, we show how knowledge about the distributions of delayed passengers can be used in order to set up a stochastic programming framework.

Telecommunications & networks

Thu.1.H 3503

Allocation problems

Chair Anders Gullthav, NTNU (Trondheim)

Hasan Turan, University of Yalova (with Nihat Kasap)

Volume discount pricing policy for capacity acquisition and task allocation models in telecommunication with fuzzy QoS Constraints

In order to complete daily operations and to stay competitive at market, every firm has to use telecommunication networks. In this paper, we analyze single period and single objective off-line cost minimization problem of a firm under nondeterministic settings of the telecommunication network environment. In this paper, the quality of service (QoS) levels guaranteed by network providers and the minimum QoS level which is needed for accomplishing operations without interruption are denoted as fuzzy numbers in order to absorb the imprecise nature of the real world telecom problems. The mathematical formulation of the aforementioned problem leads to the non-linear mixed integer programming model with fuzzy constraints. Thus, we propose a fuzzy set theory based novel heuristic algorithm procedure that have the capability of solving complex vendor selection and task allocation problems in communication networks by considering volume discounts offered by telecommunication capacity suppliers. Finally, the efficiency of algorithm is tested on several test scenarios to demonstrate the applicability of the methodology to assist decision makers.

Anders Gullthav, NTNU (Trondheim) (with Bjørn Nygreen)

Service deployment in cloud data centers regarding quality of service (QoS) requirements

Cloud computing and its Software-as-a-Service (SaaS) model has made impact on the way ICT services are being delivered to the users, and gives providers more flexibility in scaling the services according to the demand. In the provisioning, a SaaS provider needs to focus on cost- and energy-efficient operation of its private cloud, and ensure that the services deployed on the nodes in the cloud have a QoS satisfying the agreed requirements. In this talk, we mainly focus on decisions of a SaaS provider related to the management of his services and cloud data centers, but also acknowledge decisions related to bursting services into public clouds. A service is modeled as a collection of distinct components, and increased QoS is obtained by adding active or passive copies of these, leading to several ways to satisfy the QoS requirements. We will present (M)IP models of a problem where the goal is to minimize the cost of running services in private and public clouds, while ensuring satisfactory QoS. Firstly a direct formulation is created, and then we reformulate the model, utilizing column generating techniques with pregeneration of node patterns, by which we achieve better results.

Deepak Garg, Panjab University (with Harendra Kumar, Manisha Sharma)

Heuristic mathematical models for solving dynamic task assignment problem in distributed real time systems

Efficient task scheduling is a crucial step to achieve high performance for multiprocessor platform remains one of the challenging problems despite of the numerous studies. In a distributed real time systems (DRTS) the tasks of a program must be assigned dynamically to the heterogeneous processors, so as to utilize the computational capabilities and resources of the system efficiently. This paper deals with dynamical task assignment problem for allocating the m tasks of distributed program to n heterogeneous processors ($m > n$) to minimize the total cost of the program, which permits each task to be migrated from one processor to another during the execution of the program. To design the mathematical model, phase wise execution cost (EC), inter-task communication cost (ITCC), migration cost (MC) and residence cost (RC) of each task on each processor has been taken in the form of matrices.

Variational analysis

Thu.1.H 2035

Structure and stability of optimization problems

Chair Jan-J. Ruckmann, University of Birmingham

Jan-J. Ruckmann, University of Birmingham

Max-type objective functions: A smoothing procedure and strongly stable stationary points

We consider the minimization of a max-type function over a feasible set M and apply the concept of strongly stable stationary points to this class of problems. We use a logarithmic barrier function and construct a family M^Y of interior point approximations of M where M^Y is described by a single smooth inequality constraint. We show that there is a one-to-one correspondence between the stationary points (and their

corresponding stationary indices) of the original problem and those with the feasible set M^y .

Helmut Grerer, Johannes Kepler University Linz

Second-order conditions for a class of nonsmooth programs

We study infinite dimensional optimization problems with constraints given in form of an inclusion $0 \in F(x) - S(x)$, where F denotes a smooth mapping and S is a generalized polyhedral multifunction, e.g., the normal cone mapping of a convex polyhedral set. By using advanced techniques of variational analysis we obtain second-order characterizations, both necessary and sufficient, for directional metric subregularity of the constraint mapping. These results can be used to obtain second-order optimality conditions for the optimization problem.

Peter Fousek, Comenius University Bratislava

On metric regularity of the Kojima function in nonlinear semidefinite programming

The one-to-one relation between the points fulfilling the KKT conditions of an optimization problem and the zeros of the corresponding Kojima function is well-known. In the present paper we study the interplay between metric regularity and strong regularity of this a priori nonsmooth function in the context of semidefinite programming. Having in mind the topological structure of the positive semidefinite cone we identify a class of Lipschitz metrically regular functions which turn out to have coherently oriented B-subdifferentials. This class is broad enough to include the Kojima function corresponding to the nonlinear semidefinite programming problem.

Variational analysis

Thu.1.H 2051

Optimization methods for nonsmooth inverse problems in PDEs

Organizers/Chairs Akhtar Khan, Rochester Institute of Technology; Christian Clason, Karl-Franzens-Universität Graz · Invited Session

Barbara Kaltenbacher, Alps-Adriatic University of Klagenfurt (with Bernd Hofmann, Frank Schöpfer, Thomas Schuster)

Iterative regularization of parameter identification in PDEs in a Banach space framework

Natural formulations of inverse problems for PDEs often lead to a Banach space setting, so that the well-established Hilbert space theory of regularization methods does not apply. The talk will start with an illustration of this fact by some parameter identification problems in partial differential equations. Then, after a short detour to variational regularization, we will mainly focus on iterative regularization methods in Banach spaces. We will dwell on gradient and Newton type methods as well as on their extension from the original Hilbert space setting to smooth and convex Banach spaces. Therewith, convexity of the Newton step subproblems is preserved while often nondifferentiability might be introduced, which results in the requirement of solving a PDE with nonsmooth nonlinearity for evaluating the duality mapping. Convergence results for iterative methods in a Banach space framework will be discussed and illustrated by numerical experiments for one of the above mentioned parameter identification problems.

Bernd Hofmann, TU Chemnitz

On smoothness concepts in regularization

A couple of new results on the role of smoothness and source conditions in Tikhonov type regularization in Hilbert and Banach spaces are presented. Some aspect refers to the the role of appropriate choice rules for the regularization parameter. The study is motivated by examples of nonlinear inverse problems from inverse option pricing and laser optics.

Christian Clason, Karl-Franzens-Universität Graz

Inverse problems for PDEs with uniform noise

For inverse problems where the data is corrupted by uniform noise, it is well-known that the L^∞ norm is a more robust data fitting term than the standard L^2 norm. Such noise can be used as a statistical model of quantization errors appearing in digital data acquisition and processing. Although there has been considerable progress in the regularization theory in Banach spaces, the numerical solution of inverse problems in L^∞ has received rather little attention in the mathematical literature so far, possibly due to the nondifferentiability of the Tikhonov functional. However, using an equivalent formulation, it is possible to derive optimality conditions that are amenable to numerical solution by a superlinearly convergent semi-smooth Newton method. The automatic choice of the regularization parameter α using a simple fixed-point iteration is also addressed. Numerical examples illustrate the performance of the proposed approach as well as the qualitative behavior of L^∞ fitting.

Approximation & online algorithms

Thu.2.H 3010

Scheduling, packing and covering

Organizer/Chair Nicole Megow, Technische Universität Berlin · Invited Session

Wiebke Höhn, TU Berlin (with Tobias Jacobs)

On the performance of Smith's rule in single-machine scheduling with nonlinear cost

We consider the problem of scheduling jobs on a single machine. Given some continuous cost function, we aim to compute a schedule minimizing the weighted total cost, where the cost of each individual job is determined by the cost function value at the job's completion time. This problem is closely related to scheduling a single machine with nonuniform processing speed. We show that for piecewise linear cost functions it is strongly NP-hard.

The main contribution of this article is a tight analysis of the approximation factor of Smith's rule under any particular convex or concave cost function. More specifically, for these wide classes of cost functions we reduce the task of determining a worst case problem instance to a continuous optimization problem, which can be solved by standard algebraic or numerical methods. For polynomial cost functions with positive coefficients it turns out that the tight approximation ratio can be calculated as the root of a univariate polynomial. To overcome unrealistic worst case instances, we also give tight bounds that are parameterized by the minimum, maximum, and total processing time.

Christoph Dürr, CNRS, Univ. Pierre et Marie Curie

Packing and covering problems on the line as shortest path problems

A popular approach to understand a new problem is to model it as an integer linear program, and to analyze properties of the relaxed linear program. Sometimes one might discover the the variable-constraint matrix is totally unimodular (TUM), which implies that the problem has a polynomial time solution, most likely with a flow structure. In some cases however the linear program is not TUM, but nevertheless has the property, that whenever it has a solution, all optimal extrem point solutions are integral. Again this leads to a polynomial time solution, just by solving the relaxed linear program. D. and Mathilde Hurand in 2006 found that some of these linear programs could be simplified as shortest path formulations. In 2011 Alejandro López-Ortiz and Claude-Guy Quimper showed how the special structure of these shortest path instances could be used to solve the problem within improved running time. In this talk the outline of these analysis and simplification techniques are presented, illustrated on packing and covering problems on the line.

Alexander Souza, Apixox AG (with Matthias Hellwig)

Approximation algorithms for generalized and variable-sized bin covering

We consider the NP-hard Generalized Bin Covering problem: We are given m bin types, where each bin of type i has profit p_i and demand d_i . There are n items, where item j has size s_j . A bin of type i is covered if the set of items assigned to it has total size at least the demand d_i . Then the profit of p_i is earned and the objective is to maximize the total profit. To the best of our knowledge, only the cases $p_i = d_i = 1$ (Bin Covering) and $p_i = d_i$ (Variable-Sized Bin Covering) have been treated before. We study two models of bin supply: In the unit supply model, we have exactly one bin of each type and in the infinite supply model, we have arbitrarily many bins of each type.

We prove that there is a combinatorial 5-approximation algorithm for Generalized Bin Covering with unit supply, which has running time $O(nm\sqrt{m+n})$. For Variable-Sized Bin Covering, we show that the Next Fit Decreasing (NFD) algorithm is a 9/4-approximation in the unit supply model. We also show that there is an FPTAS for Variable-Sized Bin Covering in the infinite supply model.

Combinatorial optimization

Thu.2.H 3004

Cycles in graphs

Chair Peter Recht, TU Dortmund

Eva-Maria Sprengel, TU Dortmund, Germany (with Peter Recht)

An optimal cycle packing for generalized Petersen graphs $P(n, k)$ with k even

For an undirected graph $G = (V, E)$ a maximum cycle packing is a collection of pairwise edge-disjoint cycles. The maximum cardinality of such a packing is denoted as the cycle packing number $\nu(G)$.

In general the determination of a maximum cycle packing and the cycle packing number, respectively, is NP-hard.

In this lecture we consider the family of generalized Petersen graphs $P(n, k)$ with k even. We give a lower and an upper bound on

the cycle packing number and outline the structure of one optimal cycle packing of such graphs.

Peter Recht, TU Dortmund (with Eva-Maria Sprengel)

A “min-max-theorem” for the cycle packing problem in Eulerian graphs

This lecture deals with the problem to determine a set $\mathcal{Z}^* = \{C_1, C_2, \dots, C_{\nu(G)}\}$ of edge-disjoint cycles of maximum cardinality $\nu(G)$ in a graph $G = (V, E)$. The problem is tackled by considering special subgraphs:

for a vertex $v \in V$, let $T(v)$ be a *local trace* at v , i.e. $T(v)$ is an Eulerian subgraph of G such that every walk $W(v)$, with start vertex v can be extended to an Eulerian tour in $T(v)$.

In general, maximal local traces are not uniquely defined but their packing numbers $\nu(T(v))$ are.

We prove that if G is Eulerian every maximum edge-disjoint cycle packing \mathcal{Z}^* of G induces maximum local traces $T(v)$ at v for every $v \in V$. In the opposite, if the total size $\sum_{v \in V} |E(T(v))|$ is minimal then the set of induced edge-disjoint cycles in G must be maximum.

The determination of such a maximal trace leads to a multi-commodity flow-problem with quadratic objective function.

Lamia Aoudia, University of Sciences and Technologies Houari Boumediel (U.S.T.H.B) (with Meziane Aider)

4-cycle polytope on a graph

The aim of this work is to give a convex hull of 4-cycle on a wider class of complete bipartite graphs.

Given a bipartite graph $K_{n,m}$, where $|V_1| = n$ and $|V_2| = m$, $E = V_1 \times V_2$ and a weight function $w : E \rightarrow \mathbb{R}$, The *minimum weighted 4-cycle problem* consist on finding a 4-cycle $C \subset E$ such that $\sum_{e \in C} w_e$ is minimum. This problem can easily be solved in polynomial time by complete enumeration of the the 4-cycles of G . For each 4-cycle C , let \mathcal{X}^C denote the incidence vector of C defined by: $\mathcal{X}^C(e) = 1$ and $\mathcal{X}^C = 0$ if $e \notin C$. The 4-cycle polytope $PC_{n,m}^4$ is the convex hull of the incidence vectors of the 4-cycles of $K_{n,m}$, i.e. $PC_{n,m}^4 = \text{conv hull} \{ \mathcal{X}^C \in \{0, 1\} : C \text{ is a 4-cycle of } G \}$ The minimum weighted 4-cycle problem is clearly equivalent to the linear program

$$\min \{ wx : x \in PC_{n,m}^4 \}.$$

We are mainly interested by the facial structure of $PC_{n,m}^4$. Thus, we enumerate some inequalities defining facets of $PC_{n,m}^4$.

Combinatorial optimization

Thu.2.H 3005

Distance geometry and applications

Organizers/Chairs Antonio Mucherino, IRISA; Nelson Maculan, Federal University of Rio de Janeiro (UFRJ) · Invited Session

Carlile Lavor, State University of Campinas (with Leo Liberti, Nelson Maculan, Antonio Mucherino)

A discrete approach for solving distance geometry problems related to protein structure

Nuclear Magnetic Resonance (NMR) experiments can provide distances between pairs of hydrogens of a protein molecule. The problem of identifying the coordinates of all atoms of a molecule by exploiting the information on the distances is a Molecular Distance Geometry Problem (MDGP). A particular ordering is given to the hydrogens and also to the atoms of the protein backbone which allows to formulate the MDGP as a combinatorial problem, called Discretizable MDGP (DMDGP). We will talk about our efforts that have been directed towards adapting the DMDGP to be an ever closer model of the actual difficulties posed by the problem of determining protein structures from NMR data.

Pedro Nucci, Navy Arsenal of Rio de Janeiro (with Carlile Lavor, Loana Nogueira)

Solving the discretizable molecular distance geometry problem by multiple realization trees

The Discretizable Molecular Distance Geometry Problem (DMDGP) is a subclass of the MDGP, which can be solved using a discrete method called Branch-and-Prune (BP) algorithm. We present an initial study showing that the BP algorithm may be used differently from its original form, which fixes the initial atoms of a molecule and then branches the BP tree until the last atom is reached. Particularly, we show that the use of multiple BP trees may explore the search space faster than the original BP.

Deok-Soo Kim, Hanyang University

Molecular distance geometry problem: A perspective from the Voronoi diagram

Molecular distance geometry problem (MDGP) is to determine the three-dimensional structure of biomolecule from a subset of distances between pairs of atoms constituting the molecule. MDGP is important because molecular structure is critically used for understanding molecular function, particularly for NMR technology. There have been vari-

ous approaches for solving MDGP such as branch-and-prune, geometric build-up, global optimization, etc. It is interesting to note that it is hard to find any approach based on the Voronoi diagram despite that the MDGP is an intrinsic geometric problem among neighboring atoms. The Voronoi diagram of atoms, the additively-weighted Voronoi diagram in computational geometric term, represents the correct proximity among atoms in a compact form and is very useful for efficiently and correctly solving any kinds of shape-related molecular structure problem. In this presentation, we will discuss a potentially useful approach to connect the Voronoi diagram of atoms with an efficient solution of the MDGP.

Combinatorial optimization

Thu.2.H 3008

Discrete structures and algorithms II

Organizer/Chair Satoru Fujishige, Kyoto University · Invited Session

Akiyoshi Shioura, Tohoku University

Computing the convex closure of discrete convex functions

We consider computational aspect of the convex closure of discrete convex functions. More precisely, given a discrete convex function defined on the integer lattice, we consider an algorithm for computing the function value and a subgradient of the convex closure at a given point. Such an algorithm is required when the continuous relaxation approach is applied to nonlinear integer programs. In the theory of discrete convex analysis, two classes of discrete convex functions called M-/L-convex functions play primary roles; an M-convex function is a function defined on an integral polymatroid, while an L-convex function can be seen as an extension of a submodular set function. While the convex closure of an L-convex function can be expressed by a simple formula, it is not clear how to compute the convex closure of an M-convex function. In this talk, we show that the function values and subgradients of the convex closure of an M-convex function can be computed efficiently. This result is shown by making full use of conjugacy results of discrete convex analysis.

Naoyuki Kamiyama, Kyushu University

Matroid intersection with priority constraints

In this paper, we consider the following variant of the matroid intersection problem. We are given two matroids M_1 and M_2 on the same ground set S and a subset A of S . Our goal is to find a common independent set I of M_1 and M_2 such that $|I \cap A|$ is maximum among all common independent sets of M_1 and M_2 and such that (secondly) $|I|$ is maximum among all common independent sets of M_1 and M_2 satisfying the first condition. This problem can be solved by reducing it to the weighted matroid intersection problem. In this paper, we consider the following question: Is reduction to the weighted matroid intersection inevitable? We prove that our problem can be solved by using a Dulmage-Mendelsohn decomposition without reduction to the weighted matroid intersection problem.

Britta Peis, TU Berlin (with Tobias Harks)

Resource buying games

In resource buying games, players jointly buy a subset of a given resource set. As in classical congestion games, each player has a pre-defined family of subsets of the resources from which she needs at least one to be available. However, a resource is only available if the sum of payments of all players cover the load-dependent cost of that resource. A strategy of a player is therefore a tuple consisting of one of her resource sets together with a payment vector indicating how much she is willing to contribute towards the purchase of each resource. During the talk, we study the existence and computability of pure Nash equilibria (PNEs) in resource buying games. Resource buying games reduce to connection games in the special case where the costs are fixed and the players' resource sets are network-paths connecting two player-specific terminals. While there exist very simple connection games without PNE, we will see that PNEs exist and can be efficiently computed if each player's strategy set is the base set of a matroid and the marginal cost of each resource is monotone.

Combinatorial optimization

Thu.2.H 3012

Nonlinear combinatorial optimization

Chair Laura Klein, TU Dortmund

Laura Klein, TU Dortmund (with Christoph Buchheim)

Separation algorithms for quadratic combinatorial optimization problems

Binary quadratic optimization problems (BQP) are known to be NP-hard even in the unconstrained case. The standard linearization, where

auxiliary variables replace the quadratic monomials, yields an exact IP-formulation, but the resulting LP-bounds are weak in general. For BQPs whose underlying linear problem is efficiently solvable, we propose an improved approach. We consider the corresponding problem with only one monomial in the objective function and observe that valid inequalities of the single monomial problem remain valid for the general case. With the aid of an extended formulation, a polynomial time separation algorithm for the single monomial problem is presented, which exploits the simple structure of the linear case and is extendable to BQP with a constant number of monomials. The idea of separating valid inequalities in the single monomial case is applied to the quadratic minimum spanning tree problem (QMST). We present a new class of facets for QMST with one monomial and, similarly to the linear case, exploit its combinatorial structure for obtaining an efficient separation algorithm. Computational results show the advantages of the resulting inequalities for QMST.

Agnès Gorge, University Paris-Sud, LRI (with Abdel Lisser, Riadh Zorgati)

Quadratic cuts for semidefinite relaxation of combinatorial problems

Semidefinite Programming is well-known for providing tight relaxations of combinatorial problems. In practice, only few real-world applications of this approach have been reported, especially on 0/1 Linear Programming, which is yet a large part of practical combinatorial problems. The reasons for this are twofold. First, some powerful MILP software are already available. Furthermore, for such problems, it is necessary to tighten the basic semidefinite relaxation with cuts, since as it is, it is equivalent to the linear relaxation. Then, we face the difficulty of picking the right cuts to tighten the relaxation in the most relevant fashion. These cuts might be quadratic, in order to outperform the linear relaxation. We present here a systematic approach to compute such cuts. This method extends naturally to binary programs with non-convex quadratic constraints, for which no dedicated software are currently available. Finally, we apply this technique to a well-known problem of energy management i.e., the scheduling of the nuclear outages, a combinatorial problem with quadratic objective and non-convex quadratic constraints. Numerical results on real life instances are given.

Marta Vidal, Universidad Nacional del Sur- Universidad Tecnológica Nacional FRBB (with María Maciel)

A new proposal for a lower bound in a generalized quadratic assignment problem applied to the zoning problem

Zoning is a key prescriptive tool for administration and management of protected areas. However, the lack of zoning is common for most protected areas in developing countries and, as a consequence, many protected areas are not effective in achieving the goals for which they were created. In this work we introduce a quantitative method to expeditiously zone protected areas. Zoning problem was mathematically modeled as a generalized quadratic assignment problem (GQAP), this problem generalizes the well known quadratic assignment problem, one of the most difficult problems in the combinatorial optimization field, it belongs to the NP-hard class. To solve it we applied a simulated annealing heuristic, obtaining satisfactory results in both academic problems of different dimensions as a real large scale problem. In this work we propose a lower bound for the GQAP based on a new Lagrangean relaxation, which will be applied to the simulated annealing algorithm.

Combinatorial optimization

Thu.2.H 3013

Inverse problems

Chair Peter Gritzmann, TU München

Natalia Shakhlevich, University of Leeds (with Peter Brucker)

On general methodology for solving inverse scheduling problems

The talk will provide a summary of the results developed for solving inverse optimisation problems in application to scheduling. For an inverse scheduling problem, a target (non-optimal) solution is given and the objective is to adjust problem parameters (e.g., job weights, their processing times or due dates) so that the target solution is optimal while the deviation from the original parameters is as small as possible. The common methodology for solving inverse scheduling problems consists of the following two steps: (1) formulating necessary and sufficient optimality conditions which characterize optimal schedules and (2) developing efficient procedures for adjusting problem parameters in order to achieve optimality of a given solution. In the talk we provide new examples of the necessary and sufficient optimality conditions. We also show that the formulated conditions allow reformulating some in-

verse scheduling problems as dual network flow problems defined on networks of a special structure.

Daniele Catanzaro, Université Libre de Bruxelles (with Roberto Aringhieri, Marco Di Summa, Raffaele Presenti)

An exact algorithm to reconstruct phylogenetic trees under the minimum evolution criterion

We investigate one of the most important \mathcal{NP} -hard versions of the phylogeny estimation problem, called the Minimum Evolution Problem (MEP). Specifically, we investigate the theoretical foundation of the MEP and its relationships with the Balanced Minimum Evolution Problem. Moreover, we present a new exact approach to solution of the MEP based on a sophisticated combination of both a branch-price-and-cut approach and a non-isomorphic enumeration of all possible phylogenies for a set of n taxa. This peculiar approach allows to break symmetries in the problem and to improve upon the performances of the best-so-far exact algorithm for the MEP. Hopefully, our findings will provide new perspective on the mathematics of the MEP and suggest new directions on the development of future efficient exact approaches to solution of the problem.

Peter Gritzmann, TU München (with Andreas Alpers, Barbara Langfeld, Markus Wiegelmann)

On some discrete inverse problems: Combinatorial optimization in discrete and refraction tomography

Discrete Tomography is concerned with the retrieval of finite or finitely presented sets in some \mathbb{R}^d from their X-rays in a given finite number of directions. In the talk we focus on recent results on uniqueness and reconstruction issues. In particular, we give new conditions on when a subset J of possible positions is already determined by the given data that allow us to settle conjectures of Kuba (1997) and of Brunetti & Daurat (2005). Further, we indicate how new challenges in refraction tomography relate to issues in computational convexity.

Combinatorial optimization

Thu.2.H 3021

Combinatorial optimization under uncertainty

Organizer/Chair Bo Chen, University of Warwick - Invited Session

Xiuli Chao, University of Michigan (with Beryl Chen)

Dynamic pricing decision for a monopoly with strategic customers and price adjustment

We consider a monopoly firm selling a product over a finite planning horizon to a finite customer base. Each customer requires at most one product and decides whether and when to purchase the product. The customers are strategic and forward looking in making their purchasing decisions. The firm's objective is to set the selling price in each period to maximize its total discounted revenue. We analyze the effect and benefit for the firm's strategy to offer a price adjustment. Our research questions are the following: How does the price adjustment strategy affect the optimal selling price in each period and the consumer behavior, who benefits and who is hurt by this price adjustment strategy? The problem is modeled as a dynamic game and we obtain Markov subgame perfect equilibrium. We show that, depending on the system parameters, the optimal pricing strategy has several interesting patterns. These results are then applied to answer the research questions raised above. We also offer the managerial insights yielded from this model.

Mahdi Noorizadegan, Warwick Business School, Warwick University (with Bo Chen, Laura Galli)

A branch and cut approach for some heterogeneous routing problems under demand uncertainty

The Capacitated Vehicle Routing Problem (CVRP), with its many variants, is one of the most widely studied NP-hard problems in combinatorial optimisation due to its wide practical applications and tough computational challenges. An important generalisation of the classical CVRP is the so-called Heterogeneous Vehicle Routing Problem (HVRP), where a heterogeneous fleet of finite vehicles is stationed at the depot. In this study, we first consider the stochastic HVRP, and then move to a new and even more general variant known as (stochastic) Capacitated Multi-Depot Heterogeneous VRP. In the stochastic versions it is assumed that customer demands are not known for certain. There are many ways to deal with uncertainty. We present three models: two robust counterparts according to Ben-Tal & Nemirovski (1999) and Bertsimas & Sim (2004) and one chance-constrained. Our first step is to formulate the (deterministic) problems in such a way that the corresponding stochastic ones, according to the three frameworks, remain tractable. The second step is to solve the resulting models using a Branch-and-Cut approach. We present heuristic separation algorithms for some classes of valid inequalities.

Zhichao Zheng, National University of Singapore (with Chung Piaw Teo)

Least square regret in stochastic discrete optimization

We describe an approach to find good solution to combinatorial op-

timization problem, when the objective function is random. We use the notion of least square regret, i.e., the expected squared deviation from the optimal solution with perfect hindsight, to measure the performance of the proposed solution. This mimics the tracking error minimization approach often used in the portfolio optimization literature.

Complementarity & variational inequalities

Thu.2.MA 313

Iterative methods for variational inequalities

Organizers/Chairs Igor Konnov, Kazan University; Vyacheslav Kalashnikov, ITESM, Campus Monterrey · Invited Session

Igor Konnov, Kazan University

Extended systems of primal-dual variational inequalities

A system of variational inequalities with general mappings, which can be regarded as an extension of Lagrangean primal-dual systems of constrained problems, is considered. Many equilibrium type problems can be written in this format. In particular, we show that this problem is suitable for modelling various complex systems including spatial telecommunication, transportation, and economic ones. However, the basic mappings can be multi-valued and even non-monotone in real applications. This fact creates certain difficulties for providing convergence of many existing iterative methods.

In this talk, we describe several families of iterative solution methods for the above system which are adjusted to the mappings properties. In particular, they are applicable both for the single-valued and for the multi-valued case. Next, the methods are convergent under mild conditions and admit efficient computational implementation especially for the spatially distributed problems.

Alexander Zaslavski, The Technion - Israel Institute of Technology

The extragradient method for solving variational inequalities in the presence of computational errors

In a Hilbert space, we study the convergence of the subgradient method to a solution of a variational inequality, under the presence of computational errors. Most results known in the literature establish convergence of optimization algorithms, when computational errors are summable. In the present paper, the convergence of the subgradient method for solving variational inequalities is established for non-summable computational errors. We show that the subgradient method generates a good approximate solution, if the sequence of computational errors is bounded from above by a constant.

Vyacheslav Kalashnikov, ITESM, Campus Monterrey (with Yazmin Acosta Sanchez, Nataliya Kalashnykova)

Finding a conjectural variations equilibrium in a financial model by solving a variational inequality problem

In this paper, a general multi-sector, multi-instrument model of financial flows and prices is developed, in which the utility function for each sector is assumed to be quadratic and constraints satisfy a certain accounting identity that appears in flow-of-funds accounts. Each sector uses conjectures of its influence upon the prices of instruments. The equilibrium conditions are first derived, and then the governing variational inequality is presented. Next, a criterion of consistency of the conjectures is derived, and a qualitative analysis of the model is conducted.

Conic programming

Thu.2.H 2036

Conic relaxation approaches for scheduling and selection problems

Chair Yuan Yuan, The Logistics Institute, Northeastern University

Karthik Natarajan, Singapore University of Technology and Design (with Vinit Kumar Mishra, Dhanesh Padmanabhan, Chung-Piaw Teo)

On theoretical and empirical aspects of marginal distribution choice models

In the discrete choice context, two recently proposed models are the marginal distribution model (MDM) and marginal moment model (MMM), using only limited information of joint distribution of random utilities (marginal distributions and first two marginal moments, respectively). In this paper, we show that multinomial logit (MNL) and MMM choice probabilities are special cases of MDM for exponential and t-distributions. The choice probabilities obtained using the generalized extreme value (GEV) models is also a special case of the MDM with generalized exponential distributions. The convexity of the maximum log-likelihood estimation problem is established for a class of distributions from the theory of constrained optimization. We show that the seller's problem of determining the prices of multiple differentiated products

to maximize the expected profit can be formulated as a concave maximization problem for the class of logconcave density functions. Conjoint choice data set on technological features for automobiles, provided by General Motors is used to test the performance of the models.

Yuan Yuan, The Logistics Institute, Northeastern University (with Tang Lixin)

Integrated ship plan of strip coil consolidation and stowage

In iron and steel industry, finished products such as strip coils are mainly transported by ship. The planning of ship transportation includes consolidation planning and stowage planning. Consolidation planning is to determine which coils to be loaded on a given ship according to the delivery dates, destinations and storage locations of the coils. Stowage planning is to allocate exact position to each coil based on the constraints about the ship's stability. Ordinary researches divided the problem into two subproblems, and discussed them sequentially. The solution obtained by solving the two problems may not be very good or there may be many shifts, or even not all the coils in consolidation plan could be loaded. This is because the size of coils is irregular and the constraints for balance are rigorous, but the frame of ship was not considered by consolidation planning. The situation motivates us to integrate the two subproblems. We formulate the problem and relax it by a second order cone programming approach. An approximate solution is obtained by a heuristic method.

Conic programming

Thu.2.H 2038

Interior-point methods for conic programming

Chair Bo Kyung Choi, Pukyong National University, Busan, Republic of Korea

Chek Beng Chua, Nanyang Technological University

Weighted analytic centers for convex conic programming

We extend the target map, together with the weighted barriers and the weighted analytic centers, from linear programming to general convex conic programming. This extension is obtained from a novel geometrical perspective of the weighted barriers, that views a weighted barrier as a weighted sum of barriers for a strictly decreasing sequence of faces. Using the Euclidean Jordan-algebraic structure of symmetric cones, we give an algebraic characterization of a strictly decreasing sequence of its faces, and specialize this target map to produce a computationally-tractable target-following algorithm for symmetric cone programming. The analysis is made possible with the use of triangular automorphisms of the cone, a new tool in the study of symmetric cone programming.

Roland Hildebrand, Univ. Grenoble 1 / CNRS

A barrier on convex cones with parameter equal to the dimension

Self-concordant barriers are central in interior-point methods for conic programming. The speed of interior-point methods based on a particular barrier depends on a scalar parameter, the barrier parameter. Nesterov and Nemirovski showed that the universal barrier, which exists and is unique for every regular convex cone, has a barrier parameter of order $\mathcal{O}(n)$, where n is the dimension of the cone. We present another barrier, the Einstein-Hessian barrier, which also exists and is unique for every regular convex cone, but has barrier parameter equal to n . In addition to compatibility with taking product cones and invariance with respect to unimodular automorphisms of the cone, which it shares with the universal barrier, the Einstein-Hessian barrier is also compatible with duality. The level surfaces of the Einstein-Hessian barrier are characterized by the property of being affine hyperspheres, objects well-known in differential geometry. We give also another, more intuitive geometric characterization of these level surfaces. They are minimal surfaces in the product of the primal and dual projective spaces associated to the ambient real spaces where the cone and its dual reside.

Bo Kyung Choi, Pukyong National University, Busan, Republic of Korea (with Gue Myung Lee)

New large-update primal-dual interior-point algorithms for symmetric optimization problems

A linear optimization problem over a symmetric cone, defined on a Euclidean Jordan algebra and called a symmetric optimization problem (shortly, SOP), is considered. We formulate a large-update primal-dual interior-point algorithm for SOP by using the proximity function defined by a new kernel function, and obtain complexity results for our algorithm by using the Euclidean Jordan algebra techniques.

Derivative-free & simulation-based opt.**Thu.2.H 3003A****Addressing noise in derivative-free optimization**

Organizers/Chairs Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory · Invited Session

Stefan Wild, Argonne National Laboratory

Computational noise in simulation-based optimization

Efficient simulation of complex phenomena often results in computational noise. Noise destroys underlying smoothness that otherwise could benefit optimization algorithms. We present a non-intrusive method for estimating computational noise and show how this noise can be used to derive finite-difference estimates with provable approximation guarantees. Building upon these results, we show how step sizes for model minimization and improvement can be selected. These techniques can also be used to determine when to transition from interpolation-based to regression-based surrogate models in derivative-free optimization.

Stephen Billups, University of Colorado Denver

Managing the trust region and sample set for regression model based methods for optimizing noisy functions without derivatives

The presence of noise or uncertainty in function evaluations can negatively impact the performance of model based trust-region algorithms for derivative free optimization. One remedy for this problem is to use regression models, which are less sensitive to noise; and this approach can be enhanced by using weighted regression. But this raises questions of how to efficiently select sample points for model construction and how to manage the trust region radius, taking noise into account. This talk proposes strategies for addressing these questions and presents an algorithm based on these strategies.

Anke Tröltzsch, CERFACS Toulouse (with Serge Gratton, Philippe Toint)

A model-based trust-region algorithm for derivative-free optimization and its adaptation to handle noisy functions and gradients

Optimization algorithms are crucial to solve industrial optimization problems characterized by different requirements. Depending on the availability of the gradient, different algorithms have been developed such as Derivative-Free Optimization (DFO) or gradient-based algorithms. The software BC-DFO (Bound-Constrained Derivative-Free Optimization), using a self-correcting property of the geometry and an active-set strategy to handle bound constraints, has shown to be efficient on a set of test problems of the CUTER collection. Here, we propose to extend this code by adding the possibility of handling noisy gradient information. It is well known that the L-BFGS method is a very efficient method for solving bound-constrained optimization problems when accurate gradient information is provided. Whereas, this is often not the case in practice. We would like to propose a family of algorithms which contains both, the derivative-free approach and the L-BFGS method, and which is therefore able to optimally take into account the error occurring in the cost function and/or gradient of the problem. We will present numerical experiments on academic and real-life test cases.

Finance & economics**Thu.2.H 3027****Optimization and economic applications**

Organizer/Chair Kenneth Judd, Hoover Institution · Invited Session

Sebastián Lozano, University of Seville

Choosing the best partner for a horizontal cooperation

In this paper Data Envelopment Analysis is used to select among different potential partners to form a joint venture which is the one that best fits the strategic goal of a horizontal cooperation. Since each potential partner has a different technology the one whose technology better complements ours is the one that will bring the greatest synergy to the technology of the joint venture. Models for the cases that the joint venture is planning to open one or several facilities are presented. A priori and ex-post measures of synergy between the partners are proposed. Also, a simple way of sharing the costs of the horizontal cooperation based on cooperative game theory is presented.

Xiaoxuan Meng, City University of Hong Kong (with Chuangyin Dang)

An interior-point path-following method for computing equilibria of an exchange economy with linear production technologies

The computation of economic equilibria plays an important role in all applications of general economic equilibrium model. Despite the fact that some numerical methods have been proposed, how to compute economic equilibria efficiently remains a challenging issue. In this paper, we develop an interior-point path-following method for comput-

ing economic equilibria of an exchange economy with linear production technologies. The peculiar characteristic of our method is that we convert an exchange economy with linear production technologies to a pure exchange economy by ways of allocating the production to consumers' endowments evenly. Resorting to an extra variable, we devise a new economy which deforms from a trivial exchange economy to the original one while the variable varies from 0 to 1. An application of Sard's theorem and perturbations leads to the existence of a smooth interior-point path, which starts from the unique equilibrium of the exchange economy and leads to an economic equilibrium of the exchange economy with linear production technologies. A predictor-corrector method is proposed to numerically follow the path. Efficiency of the method is demonstrated through numerical examples.

Nasser-Eddine Tatar, King Fahd University of Petroleum and Minerals

Asymptotic stability for the endogenous Solow model with discrete and distributed delays

In the original Solow growth theory it is assumed that the rate of change of the labour supply is exogenous. This theory has serious limitations (failure to take account of entrepreneurs and strength institutions and failure to explain technological progress) which lead to the development of endogenous growth theories. These theories support that long-run economic growth depends on forces internal to the economic system which create technological progress. In this talk we consider a (more realistic) Solow model where the labour supply depends on the past levels of wage. We discuss both the discrete delay case and the distributed delay case. This latter model is known as the Vintage Capital Model and is widely used in economy. We shall establish some reasonable assumptions under which the economy converges to a steady-state rate of growth.

Game theory**Thu.2.MA 005****Efficiency and optimization in games**

Organizer/Chair Ioannis Caragiannis, University of Patras & CTI · Invited Session

Francesco Pasquale, Università degli Studi di Salerno (with Vincenzo Auletta, Diodato Ferraioli, Paolo Penna, Giuseppe Persiano)

Logit dynamics: Expected social welfare, mixing time, and metastability

Logit dynamics [Blume, Games and Economic Behavior, 1993] is a randomized best response dynamics for strategic games: at every time step a player is selected uniformly at random and she chooses a new strategy according to a probability distribution biased toward strategies promising higher payoffs. This process defines an ergodic Markov chain over the set of strategy profiles, whose unique stationary distribution we regard as the long-term equilibrium concept for the game. We are interested in the stationary performance of the game (the expected social welfare when the profiles are random according to the stationary distribution) and in the time it takes to get close to the stationary distribution (mixing time). When the mixing time is large the stationary distribution loses its appeal as equilibrium concept and we look for "regularities" at time-scales shorter than mixing time (metastability). In this talk we give an overview of our recent results on stationary expected social welfare, mixing time, and metastability of logit dynamics for some classes of games.

Vasilis Gkatzelis, Courant Institute, NYU (with Richard Cole, Gagan Goel)

Truthful mechanisms for proportionally fair allocations

We study the problem of designing mechanisms to allocate a heterogeneous set of divisible goods among a set of agents in a fair manner. We consider the well known solution concept of proportional fairness that has found applications in many real-world scenarios. Although finding a proportionally fair solution is computationally tractable, it cannot be implemented in a truthful manner. To overcome this, in this paper, we give mechanisms which are truthful and achieve proportional fairness in an approximate manner. We use a strong notion of approximation, requiring the mechanism to give each agent a good approximation of its proportionally fair utility. A motivating example is provided by the massive privatization auction in the Czech republic in the early 90s.

Giorgos Christodoulou, University of Liverpool (with Kurt Mehlhorn, Evangelia Pyrga)

Coordination mechanisms for selfish routing games

We reconsider the well-studied Selfish Routing game with affine latency functions. The Price of Anarchy for this class of games takes maximum value $4/3$; this maximum is attained already for a simple network of two parallel links, known as Pigou's network. We improve upon the value $4/3$, for networks of parallel links, by means of Coordination Mechanisms.

Game theory

Thu.2.MA 043

Game theory in supply chain management

Chair Tiru Arthanari, The University of Auckland

Tiru Arthanari, The University of Auckland (with Nagarajan Krishnamurthy)

Game theory and supply chain management: A survey

Recent years have seen an increasing interest in the applications of Game Theory to Supply Chain Management (SCM) and allied areas. We survey some of these results. These include applications of Non-cooperative Games to SCM where, for example, there are competing entities and Nash equilibrium is sought. We also survey applications of Cooperative Games where, for example, the Shapley value is used to share costs (or profits). Examples are [Thun, 2005] where the author discusses applications of Cooperative Game Theory to apportion profit among partners. [Cachon and Netessine, 2003] discuss non-cooperative as well as cooperative game theoretic concepts that have potential for applications to analyzing supply chains. [Esmaeili, Aryanezhad and Zeephongsekul, 2009] propose several seller-buyer supply chain models which incorporate elements of competition as well as cooperation between buyer and seller. [Shuyong et al., 2008] use game theoretic tools to analyze the cost allocation problem in supply chain coordination. Stochastic Games, Bayesian Games etc. have been finding increasing applications in SCM too, and we discuss some of these as well. Illustrative applications are discussed.

David Carfi, University of California at Riverside (with Tiru Arthanari)

Game theoretic modeling of supply chain cooperation among growers

Cooperation in supply chains is studied, by Lincoln (2010), using qualitative research methodology, based on case studies done in New Zealand. Recently, in the Horticultural New Zealand conference, the speakers explained how cooperation was working for their industries (Farmers Weekly, 2010). In this paper we examine the cooperation phenomenon from a game theoretic perspective and give a model that brings out the trajectory of equilibria that will lead to optimal participation among the coalition partners. The model considers a set of growers who can choose to form a cooperative alliance to market their produce in some external regions, while competing within the internal regions. By means of the general analytical framework of competition, studied by Carfi (2010 and 2011), and others, we show the strategies that could provide solutions in a cooperative perspective for the growers, where these feasible solutions aim at offering a win-win outcome for the growers, letting them share the pie fairly within a growth path represented by a family of non-zero sum games. The strategy requires determining the proportion of their resources they will use and how the gain will be shared.

Ravindran Gomatam, Indian Statistical Institute (with Iyengar Sudarshan)

Centrality in social networks

Centrality captures the intuitive notion of importance of nodes in a network. In the recent past there has been a flurry of activities in the science of Networks and its applications in diverse field of study thus making it a hot topic of interdisciplinary research.

In this paper we review and propose different approaches to finding influential nodes in complex networks particularly from a game theoretic point of view.

Global optimization

Thu.2.H 2053

Advances in global optimization II

Chair Alireza Doagooei, Shahid Bahonar University of Kerman

Andrei Orlov, Institute for System Dynamics and Control Theory of Siberian Branch of Russian Academy of Sciences

On an approach to special nonlinear bilevel problems

An investigation of bilevel programming problems (BPPs) in the view of elaboration of the efficient numerical methods is a challenge of contemporary theory and methods of mathematical optimization. We consider classes of BPPs where the upper level goal function is d.c. (represented by difference of two convex functions) or convex quadratic, and the lower level goal function is convex quadratic. Also we investigate BPPs with equilibrium at the lower level. The new approach to elaboration of optimistic solution methods for these classes of BPPs is proposed. The approach is based on a possibility of equivalent representation of BPPs as nonconvex optimization problems with the help of optimality conditions for the lower level problem. These nonconvex problems are solved by using the global search theory in d.c. optimization problems developed in our group for some classes of nonconvex optimization. The approach allows building efficient methods for finding global solutions in d.c. optimization problems. Computational testing of

the elaborated methods has shown the efficiency of the approach. This work is carried out under financial support of RFBR (project no. 11-01-00270a).

John Chinneck, Carleton University (with Victor Aitken, Laurence Smith)

Better placement of local solver launch points for global optimization

NLP solutions are quite sensitive to the launch point provided to the local solver, hence multi-start methods are needed if the global optimum is to be found. The drawback is that local solver launches are expensive. We limit the number of local solver launches by first using very fast approximate methods to explore the variable space to find a small number of promising locations for the local solver launches. We start with a set of random initial points, and then apply the Constraint Consensus (CC) method to quickly move to points that are close to feasibility. Clusters of the CC output points are then automatically identified; these generally correspond to disjoint feasible regions. Finally, the local solver is launched just once from each cluster, greatly improving efficiency. We frequently find a very good solution (if not the optimum solution) with very few local solver launches, and hence in relatively little time. Extensive empirical results are given.

Alireza Doagooei, Shahid Bahonar University of Kerman

Global optimization on the difference of sub-topical functions

We present the necessary and sufficient conditions for the global minimum of the difference of strictly sub-topical functions. Also, we will use the Toland-Singer formula to characterize the dual problem. Our main theoretical tool is abstract convexity.

Implementations & software

Thu.2.H 1058

Modeling languages and software II

Organizer/Chair Robert Fourer, AMPL Optimization · Invited Session

Ronald Hochreiter, WU Vienna University of Economics and Business

Optimization modeling using R

Simplifying the task of modeling optimization problems is an important task. Many commercial products have been created to support the modeling process, but none of these products has been adopted by a significantly large number of users. As soon as real-world decision problems under uncertainty have to be modeled, flexible and quick changes to the underlying model are necessary. Simplifications are crucial to implement such optimization models into some business process successfully. Furthermore, the learning overhead for users should be minimized. In this talk, we outline an approach on how to simplify optimization modeling using R and external optimization modeling languages as well as by building model generators for specific application problems. Examples from the areas of Finance and Energy will substantiate the applicability of the chosen approach.

Arnaud Schulz, IBM (with Vincent Beraudier, Frederic Delhoume)

Enterprise-class optimization-based solutions with CPLEX Optimization Studio and SPSS predictive analytics

The talk will focus on the integration of different analytics such as optimization (prescriptive analytics) and predictive analytics based on ILOG optimization and SPSS. The presentation will showcase the synergy of these two worlds. The key integration piece will be presented, that is, the connector between prescriptive (optimization) and predictive analytics (SPSS Modeler), existing in the OPL language, integrated in the the CPLEX Studio Integrated Development Environment. With this connector statistical algorithms/methods are available to feed with data any optimization model either written for math programming (CPLEX Optimizer) or constraint programming (CP Optimizer). This opens up the door for decision makers at line-of-business, IT professionals and analytics practitioners to take advantage of out-of-the-box capabilities for implementing custom planning and scheduling solutions, collaborative planning processes, to name a few.

Leo Lopes, SAS Institute

Network optimization and beyond in SAS/OR® Software

This paper demonstrates new features in the OPTMODEL procedure for network and combinatorial optimization. With PROC OPTMODEL, you can access a variety of network-based solvers by using only problem definitions instead of explicit formulations, greatly enhancing performance and scalability. You can also access most of the functionality of the SAS System by merging invocations of other SAS procedures with mathematical programming constructs that are built into the PROC OPTMODEL modeling language. The results can populate sets and arrays that can be processed further both within the modeling language itself and by using the full power of the SAS System.

Integer & mixed-integer programming

Thu.2.H 2013

Network analysis

Chair Stefan Wiesberg, Institut fuer Informatik, Universität Heidelberg

Xavier Molinero, Universitat Politècnica de Catalunya (UPC – EPSEM) (with Josep Freixas)

Variations in strict separating systems representing a linearly separable function

An important consideration when applying neural networks is predict the effect of threshold and weight perturbations on them, i.e., which is the sharpest bound one may consider for weights and threshold to maintain the linearly separable function unchangeable for designing a more robust and safer neural network. Two parameters have been introduced to measure the relative errors in weights and threshold of strict separating systems: the tolerance (Hu 1960) and the greatest tolerance (Freixas and Molinero 2008). Given an arbitrary separating system we study which is the equivalent separating system that provides maximum tolerance and maximum greatest tolerance. We present new results for the maximum tolerance and the maximum greatest tolerance, for instance, we present when the maximum tolerance and maximum greatest tolerance among all equivalent strict separating (natural) systems are attained. We also give the strict separating (natural) system that attaches the maximum tolerance for n variables. Similar results appear for the maximum greatest tolerance. Finally, we also give new results for the number of variables n and the number of types of distinguished variables k .

Arne Müller, Freie Universität Berlin

Cycle free flows in large-scale metabolic networks

Genome-scale metabolic networks are used to model all (usually around 2000) chemical reactions occurring in a biological cell. These networks are a generalization of directed hypergraphs (where the reactions are the arcs of the graph) and a specialization of realizable oriented matroids. We are interested in optimizing the flow through a given reaction in the network. We have the usual constraint of flow conservation and additionally the flow must not contain internal circuits. Internal circuits are flows that do not contain a specific subset of the reactions called exchange reactions.

We show that it is NP-hard to decide if a non-zero flow without internal circuits through a given reaction is possible. However, most genome-scale metabolic networks only contain few internal circuits. Using a specific branching strategy combined with a primal heuristic, we derive a tractability result that is also practically applicable. In fact, it very often suffices to solve only one LP.

For flux variability analysis, where we solve optimization problems for each reaction in the network, we obtain a speed-up of factor 30–300 to previous methods.

Stefan Wiesberg, Institut fuer Informatik, Universität Heidelberg (with Gerhard Reinelt)

Computing role structures in networks

In network analysis, an established way to obtain structural information is to partition the vertices into so-called regular equivalence classes. In such a partitioning, two nodes u and v belong to the same class if for every neighbor of u , there is a neighbor of v in the same class, and vice versa. Thus, for any two classes C and D , either every or no member of C has a neighbor in D . The relationships between the classes can hence be visualized by a graph, the so-called role graph. It is of interest in several fields, for example in sociology, economy, or consumer research. An NP-hard problem in this context is the following one: Given a network G and a finite set R of role graphs, which element of R represents the role structure of G in the best possible way? We present one of the first exact algorithms for this problem. It is based on an IP formulation with a quadratic objective function and solved by branch-and-cut. Significant running-time improvements compared to currently used methods are reported.

Integer & mixed-integer programming

Thu.2.H 2032

Branch-and-price III: New techniques

Organizer/Chair Marco Lübbecke, RWTH Aachen University · Invited Session

Martin Bergner, RWTH Aachen (with Marco Lübbecke)

Packing cuts with column generation

In our talk, we propose an exact algorithm for the cut packing problem in general graphs via a column generation approach. It is known that packing cuts in general graphs is NP-hard and cannot be approximated better than with a factor of $\mathcal{O}(n/\log^2 n)$ in general graphs. Cut packing has applications in both network design and, via its dual formulation as a cycle packing problem, in computational biology. For our approach, we discuss both combinatorial algorithms and a mixed-integer

linear programming (MIP) formulation for solving the pricing problems. In order to further improve the dual bound, cutting planes from the literature are separated during the solution process and their integration in the pricing problems is explained. Furthermore, we highlight a novel application for detecting structures in constraint matrices of MIPs and use heuristics tailored to this application for finding solutions during the branch-and-price algorithm. Finally, we present computational results both on graphs from the literature as well as from our application and discuss the peculiarities of these instances.

Mette Gamst, Technical University of Denmark (with Simon Spoorendonk)

An exact approach for aggregated formulations

Aggregating formulations is a powerful trick for transforming problems into taking more tractable forms. An example is Dantzig-Wolfe decomposition, which shows superior performance across many applications especially when part of a branch-and-price algorithm. Variable aggregation, however, may lead to mathematical formulations with a different solution space than that for the original formulation, i.e., the aggregated formulation may be a relaxation of the original problem. In a branch-and-bound context, variable aggregation can also lead to a formulation where branching is not trivial, for example when optimality cannot be guaranteed by branching on the aggregated variables.

In this presentation, we propose a general method for solving aggregated formulations, such that the solution is optimal to the original problem. The method is based on applying Benders' decomposition on a combination of the original and aggregated formulations. Put in a branch-and-bound context, branching can be performed on the original variables to ensure optimality. We show how to apply the method on well-known optimization problems.

Jacques Desrosiers, HEC Montréal & GERAD (with Jean Bertrand Gauthier, Marco E. Lübbecke)

Row-reduced column generation for highly degenerate master problems

Column generation alternately solves a master problem and a pricing subproblem to add variables to the master problem as needed. The method is known to suffer from degeneracy, exposing what is known as tailing-off effect. Inspired by recent advances in coping with degeneracy in the primal simplex method, we propose a row-reduced column generation that takes advantage of degenerate solutions. The idea is to reduce the number of constraints to the current number of positive basic variables. The advantage of this row-reduction is a smaller basis, and thus a faster re-optimization of the master problem. This comes at the expense of a more involved pricing subproblem that needs to generate variables compatible with the row-reduction, if possible. Otherwise, incompatible variables may need to be added, and the row-reduction is dynamically updated. We show that, in either case, a strict improvement in the objective function value occurs.

Integer & mixed-integer programming

Thu.2.H 2033

Strong relaxations for stable set and lot sizing

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Monia Giandomenico, University of L'Aquila (with Adam Letchford, Fabrizio Rossi, Stefano Smriglio)

An ellipsoidal relaxation for the stable set problem

A relevant amount of research has been focused on investigating strong relaxations for the stable set problem. In fact, polyhedral combinatorics techniques have been intensively developed since the early seventies in order to strengthen the natural linear formulation. Shortly afterwards, Lovász introduced a celebrated semidefinite programming relaxation, known as *theta relaxation*. Later on, several attempts to strengthen it by adding linear inequalities have been investigated. The resulting upper bounds turn out to be very strong, but hardly accessible in practice. In this talk, we show that the Lovász theta relaxation can be used to derive a new convex programming relaxation having the same optimal value. Moreover, the new relaxation has a more friendly structure, as its feasible region takes the form of an ellipsoid. We also investigate possible extension of this methodology to stronger relaxations.

Fabrizio Rossi, Università di L'Aquila (with Monia Giandomenico, Adam Letchford, Stefano Smriglio)

A branch-and-cut for the stable set problem based on an ellipsoidal relaxation

The stable set problem gives rise to difficult integer programs. One major reason is that linear relaxations provide weak bounds (even though at low computational cost), while semidefinite relaxations give good (sometimes excellent) bounds but too demanding to compute. The Lovász theta relaxation seems to provide the right compromise between strength and computational tractability, even if embedding it within an enumeration scheme is not straightforward. In this talk, we present a new convex programming relaxation having the theta bound as optimal value, whose feasible region takes the form of an ellipsoid. In principle,

this allows us to resort to a branch-and-cut algorithm in which each subproblem includes one convex quadratic constraint. However, the ellipsoid can also be used to derive valid inequalities for the stable set polytope: a hyperplane tangent to the ellipsoid can be exploited to generate strong cutting planes by a sequential strengthening procedure. We discuss the performance of the resulting (LP-based) branch-and-cut algorithm through extensive experiments.

Laurence Wolsey, CORE, Université Catholique de Louvain (with Mathieu Van Vyve, Hande Yaman)
The one warehouse multiple retailer problem with start-ups and constant capacities

For the uncapacitated OWMR problem with K clients and T periods, a multi-commodity reformulation solves instances with $K, T = 100$ to optimality. We consider a new relaxation motivated by the Wagner-Whitin relaxation that is effective for single level problems. The relaxed solution set X decomposes into $X = \cap_{t=1}^T Y^t$, each set Y^t having the same structure, denoted Y .

- (i) When $K = 1$ and uncapacitated at warehouse and client, we give a tight and compact extended formulation for $\text{conv}(Y)$, an inequality description in the original space, and an $O(T)$ separation algorithm.
- (ii) A similar result with start-up costs at both levels.
- (iii) With multiple clients ($K > 1$), the convex hull of Y is essentially the intersection of the convex hulls for each client individually, providing an $O(KT^2)$ formulation for X and OWMR.
- (iv) When uncapacitated at the warehouse and constant capacity for each retailer, we give an extended formulation for Y that is conjectured to be tight.

For OWMR with start-ups, our formulation improves computationally on the multicommodity formulation, and with capacities it solves to optimality instances with $K, T = 25$.

Life sciences & healthcare

Thu.2.MA 376

Scheduling, assignment and matching in healthcare

Chair Sarah Kirchner, RWTH Aachen

Andrea Trautswieser, University of Natural Resources and Life Sciences, Vienna (with Patrick Hirsch)
A branch-and-price approach for solving medium term home health care planning problems

Medium term home health care planning is important because of additional legal working time regulations. Moreover, the clients (resp. nurses) prefer to know their visiting days and times (resp. working days and times) beforehand. In Austria, the planning of these services is typically done manually. However, several constraints make the planning a time consuming task. Usually, the clients have to be visited several times a week for a certain treatment at a certain time by appropriately skilled nurses. Additionally, working time regulations such as maximum allowed working time, breaks, and rest periods have to be considered. Furthermore, some clients need to be visited by two or more nurses at the same time and some visits cannot start before a certain time gap after another visit has elapsed. The objective is to minimize the total travelling times of the nurses. In order to solve this problem efficiently an algorithm is developed combining a Branch-and-Price approach and a metaheuristic solution approach based on Variable Neighbourhood Search. The algorithm is tested with real life data and compared to the solutions obtained with standard solver software.

Nahid Jafaribagh, RMIT University (with Leonid Churilov, John Hearne)

Optimal individual matching to evaluate treatment in the stroke trails

The aim of this work is to make an individual matching of patients with multiple attributes from two groups of therapy. The problem is investigating the outcomes of the two groups of patients in the stroke trails which some treated by alteplase and the others controlled by placebo. To address the problem we modeled the problem as an integer program using assignment formulation. Our proposed models will consider the trade-off between the three objectives: maximize the number of matches, minimize the age difference, and minimize the stroke severity index difference. We applied our models for two data sets EPI-THEM and NINDS. To demonstrate the relationship between the sample size and the number of matches we did a simulation by generating thousands of patients and proved our assumptions.

Sarah Kirchner, RWTH Aachen (with Marco Lübbecke)

Appointment scheduling in a hospital environment

Currently appointments for patients are scheduled locally in most German hospitals. In every hospital unit a scheduler assigns appointments sequentially to incoming treatment requests. As the settlement amount for a patient is determined by his diagnoses and received treatments and not by the length of his hospitalization it is desirable for

hospitals to reduce the average length of hospitalization. Therefore it is necessary to coordinate appointments for all treatments on a patient's care pathway. This problem can be seen as a new variant of the well known job shop scheduling problem where patients correspond to jobs and treatments for patients correspond to tasks of jobs. The problem is also related to scheduling problems with calendars, as resources in a hospital are mostly not available at night and treatments can not be interrupted when the resource becomes unavailable. The objective of our problem is to minimize the average number of days of hospitalization. In this talk we introduce this new scheduling problem and present first models and solution approaches.

Logistics, traffic, and transportation

Thu.2.H 0106

Traffic assignment

Chair Olga Perederieieva, The University of Auckland

Olga Perederieieva, The University of Auckland (with Matthias Ehrgott, Judith Wang)

Solving the time surplus maximisation bi-objective user equilibrium model of traffic assignment

The conventional approach to model traffic assignment assumes that all users have the same objective, i.e., to minimise their travel time or generalised cost, which usually represents a linear combination of time and monetary cost. In a tolled road network, this assumption might not be adequate to represent reality. Inspired by the multi-objective definition of optimality, we reformulate the problem with a bi-objective user equilibrium (BUE) condition, which allows multiple solutions. More specifically, we propose a time-surplus maximisation model (TSMaXBUE) as a possible way to represent route choice behaviour in tolled road networks. In case of one user class it can be transformed into a time-based equilibrium model which can be solved by optimisation-based algorithms. To solve it we adopt path-based optimisation algorithms used for conventional traffic assignment, compare their performance and study how the solution space depends on the parameters of the model. In case of multiple user classes generally it is not possible to derive an equivalent optimisation formulation. Therefore, we propose to use a non-linear complementarity problem formulation to solve the TSMaXBUE model.

Alexander Gasnikov, Moscow Institute of Physics and Technology (with Evgenia Gasnikova)

Stochastic optimization in the model of correspondences matrix calculation and traffic flow distribution

We considered two problems connecting to each other. The first problem is to interpret a gravitational matrix correspondence model and its proper generalization for Moscow city according to the conception of equilibrium of macro system. We propose an ergodic stochastic Markov dynamic of natural behavior of the residents. At the large values of time this dynamic leads to the stationary distribution measure. And when the number of residents tends to infinity this measure is concentrated in a small vicinity of the most probable macro state. To find this state we have to solve an entropy optimization problem. For this problem we use proper dual barrier-multiplicative stochastic subgradient descent in dual space. The second problems consist in finding traffic flow (stochastic) assignment according to the BMW model and Nesterov-dePalma model. We show that substantially interpreted evolutionary games dynamic in this games theory models can be considered to be the mirror descent subgradient (with prox-function Kullback-Leibler distance). We also investigate the logit(Gibbs) best responses dynamic (Nash-Vardrop equilibrium isn't assumed unique).

Suh-Wen Chiou, National Dong Hwa University

Modeling the performance reliability in an area traffic control road network under uncertainty

For an urban traffic road network, most of travel time delay is directly dependent on correct and continuous operations of effective signal settings at junctions. The reliability of a road network under area traffic control thus heavily relies on its vulnerability to a dangerous mix of probabilistic threats such as system random failures, adverse weather and natural disaster. Losing capacity in one or more signal-controlled road junctions could have a negative wide impact on the performance of road network and increase total travel time on most road network users. The purpose of this paper is therefore on the focus of efforts to evaluate the performance of area traffic control road network under uncertainty which can be measured in terms of total travel time. The analysis of vulnerability of area traffic control road network is considered in this paper. The critical signal-controlled junctions of area traffic control road network are identified, when failed to perform its normal functions, could give rise to the maximum travel delay to road users.

Logistics, traffic, and transportation

Thu.2.MA 042

Synchronization and collision avoidance

Chair Torsten Gellert, TU Berlin

F. Javier Martin-Campo, University Complutense of Madrid (with Antonio Alonso-Ayuso, Laureano F. Escudero)

On solving the aircraft collision avoidance problem for the ATM by horizontal maneuvers. A ranked multiobjective MINLO problem

A mixed 0–1 nonlinear optimization approach is presented to solve the aircraft collision avoidance problem for the Air Traffic Management. Given the flight plans configuration, the problem consists of deciding a strategy such that every conflict situation is avoided. For this aim, we consider two possible maneuvers: velocity and angle changes, in a high nonconvex mixed integer nonlinear optimization (MINLO) approach that is based on a geometric construction. In order to determine which maneuvers will be followed, a ranked multiobjective approach is presented optimizing one of them by appending to it the constraint that satisfies the optimal objective function value of the other one with higher rank allowing an epsilon violation, such that the optimal solution of the higher rank objective can be used as a hot start for optimizing the other one. Some preliminary computational results will be presented by using a state-of-the-art nonconvex MINLO engine at each iteration, where a MINLO submodel is solved.

Nils-Hassan Quttineh, Linköping University (with Kaj Holmberg, Torbjörn Larsson, Kristian Lundberg)

Aircraft mission planning

We present a military aircraft mission planning problem, where the problem is to find time efficient flight paths for a given aircraft fleet that should attack a number of ground targets. Due to the nature of the attack, two aircraft need to rendezvous at the target, that is, they need to be synchronized in both space and time. Each target is associated with multiple attack options, and there may also be precedence constraints between targets, limiting the order of the attacks. The objective is to maximize the outcome of the entire attack, while also minimizing the mission timespan.

Torsten Gellert, TU Berlin (with Rolf Möhring)

Scheduling multiple cranes on a shared pathway

In many logistics applications, transport requests are conducted in parallel by several vehicles moving along a fixed shared pathway. Examples include cranes mounted on a common rail, like gantry cranes loading and unloading containers in intermodal transportation, or forklifts moving along a narrow passageway in large warehouses.

In theory, assigning transport requests to the vehicles of such systems and scheduling their execution amounts to finding k tours on a common line, where tours may never cross each other in time – dynamic collision constraints need to be respected. The goal is to minimize the makespan for a given set of transport requests. This problem contains other challenging tasks like partitioning jobs and assigning starting times.

We present a model capturing the core challenges in transport planning problems of this type and prove NP-hardness for the problem. The structural properties can be used to formulate a mixed integer program with starting time variables, but without any assignment of jobs to vehicles. Furthermore, we show some special cases where an optimal solution can be found in polynomial time.

Mixed-integer nonlinear programming

Thu.2.MA 041

Convex approaches for quadratic integer programs

Organizers/Chairs Adam Letchford, Lancaster University; Samuel Burer, University of Iowa · Invited Session

Adam Letchford, Lancaster University (with Michael Soerensen)

A new separation algorithm for the Boolean quadric and cut polytopes

A *separation algorithm* is a procedure for generating cutting planes. We present new separation algorithms for the *Boolean quadric* and *cut polytopes*, which are the polytopes associated with zero-one quadratic programming and the max-cut problem, respectively. Our approach exploits, in a non-trivial way, three known results in the literature: one on the separation of $\{0, \frac{1}{2}\}$ -cuts, one on the symmetries of the polytopes in question, and one on the relationship between the polytopes. We remark that our algorithm for the cut polytope is the first combinatorial polynomial-time algorithm that is capable of separating over a class of

valid inequalities that includes all odd bicycle wheel inequalities and all $(p, 2)$ -circulant inequalities.

Anja Fischer, Chemnitz University of Technology

The asymmetric quadratic traveling salesman problem

In the asymmetric quadratic traveling salesman problem (AQTS) the costs are associated to any three nodes that are traversed in succession and the task is to find a directed tour of minimal total cost. The problem is motivated by an application in biology and includes the angular-metric TSP and the TSP with reload costs as special cases. We study the polyhedral structure of a linearized integer programming formulation, present several classes of facets and investigate the complexity of the corresponding separation problems. Some facets are related to the Boolean quadric polytope and others forbid conflicting configurations. A general strengthening approach is proposed that allows to lift valid inequalities for the asymmetric TSP to improved inequalities for AQTS. Applying this for the subtour elimination constraints gives rise to facet defining inequalities for AQTS. Finally we demonstrate the usefulness of the new cuts. Real world instances from biology can be solved up for to 100 nodes in less than 11 minutes. Random instances turn out to be difficult, but on these semidefinite relaxations improved by the cutting planes help to reduce the gap in the root node significantly.

John Mitchell, Rensselaer Polytechnic Institute (with Lijie Bai, Jong-Shi Pang)

Quadratic programs with complementarity constraints

We examine the relationship between a quadratic program with complementarity constraints (QPCC) and its completely positive relaxation. We show that the two problems are equivalent under certain conditions, even if the complementary variables are unbounded. We describe the use of semidefinite programming to tighten up the quadratic relaxation of a QPCC when the quadratic objective function is convex. When the variables are bounded, a QPCC can be expressed as a mixed integer nonlinear program.

Multi-objective optimization

Thu.2.H 1029

Vector optimization II

Chair Xuexiang Huang, Chongqing University

Xuexiang Huang, Chongqing University

Calmness and exact penalization for constrained vector set-valued optimization problems

In this talk, we study calmness and exact penalization properties for a class of constrained vector set-valued optimization problems. We establish equivalence relationships between (local) calmness and (local) exact penalization for this class of constrained vector set-valued optimization problems. Some necessary and/or sufficient conditions for (local) calmness are also derived.

Stefan Ruzika, University of Kaiserslautern

“Vectorization” as a principle in optimization!?

It goes without saying that vector-valued optimization problems are considered to be in general more difficult than scalar-valued optimization problems. Would it ever make sense to artificially ‘vectorize’ a scalar-valued optimization problem? In this talk, I want to show an important and convincing case which demonstrates that a “vector-valued optimization”-perspective can provide new ideas for solving scalar-valued combinatorial optimization problems. This case is about the exact solution of some combinatorial optimization problems that are subject to a knapsack-type side constraint. Problems of this kind are very common and therefore important since they appear in applications and as subproblems in more complex models. This case is motivated by mathematical programming decoding (i.e., by designing decoding algorithms based on ideas from mathematical programming) and the solution techniques are illustrated using the constrained minimum spanning tree problem.

Nonlinear programming

Thu.2.H 0107

Algorithms and applications I

Organizer/Chair Ya-xiang Yuan, Chinese Academy of Sciences · Invited Session

Coralia Cartis, University of Edinburgh (with Nicholas Gould, Philippe Toint)

On the evaluation complexity of constrained nonlinear programming

We present a short-step target-following algorithm for smooth and nonconvexly constrained programming problems that relies upon approximate first-order minimization of a nonsmooth composite merit function and that takes at most $\mathcal{O}(\epsilon^{-2})$ problem-evaluations to generate an approximate KKT point or an infeasible point of the feasibility

measure. This bound has the same order as that for steepest-descent methods applied to unconstrained problems. Furthermore, complexity bounds of (optimal) order $\epsilon^{-3/2}$ are obtained if cubic regularization steps for a smooth least-squares merit function are employed in a similar target-following algorithmic framework, provided higher accuracy is required for primal than for dual feasibility.

Xiao Wang, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (with Ya-xiang Yuan)

An augmented Lagrangian trust region method for nonlinear programming

We present a new trust region method for solving equality constrained optimization problems, which is motivated by the famous augmented Lagrangian function. Different from the standard augmented Lagrangian method where the augmented Lagrangian function is minimized at each iteration, the new method, for fixed Lagrange multiplier and penalty parameter, tries to minimize an approximation model to the augmented Lagrangian function in a trust region to generate next iterate. Besides, new update strategies for Lagrange multipliers and penalty parameters are proposed. Global convergence of the new algorithm is proved in this paper. Moreover, we analyze the behavior of penalty parameters and figure out in which case when they are bounded. At last, we do some numerical experiments on the equality constrained problems from CUTER collection. We also consider extending the idea to general constrained optimization. Some numerical results are reported too.

Zhijun Wu, Iowa State University (with Yiping Hao, Wen Zhou)

Computation of optimal strategies for evolutionary games

Biological species (viruses, bacteria, parasites, insects, plants, or animals) replicate, mutate, compete, adapt, and evolve. In evolutionary game theory, such a process is modeled as a so-called evolutionary game. We describe the Nash equilibrium problem for an evolutionary game and discuss its computational complexity. We discuss the necessary and sufficient conditions for the equilibrium states, and derive the methods for the computation of the optimal strategies, including a specialized Snow-Shapley algorithm, a specialized Lemke-Howson algorithm, and an algorithm based on the solution of a complementarity problem on a simplex. Computational results are presented. Theoretical difficulties and computational challenges are highlighted.

Nonlinear programming

Thu.2.H 0110

Interior-point methods for linear programming

Chair Luiz-Rafael Santos, IMECC/Unicamp

Aurelio Oliveira, University of Campinas (with Lilian Berti, Carla Ghidini, Jair Silva)

Continued iteration and simple algorithms on interior point methods for linear programming

Continued iteration and simple algorithms are applied between interior point iterations to speed up convergence. In the continued iteration, interior point methods search directions are projected along the blocking constraint in order to continue the iteration. The process can be repeated while the projected direction is a good one in some measure. In a similar fashion, a few iterations of simple algorithms can be applied to the current interior point. Numerical experiments show that the combining such approaches leads to promising results, reducing the total number of iterations for the interior point methods applied to linear programming problems.

Luciana Casacio, UNICAMP - University of Campinas (with Christiano Lyra, Aurelio Oliveira)

New preconditioners for interior point methods in linear programming

We are concerned with the KKT systems arising when an interior point method is applied to solve large-scale linear programming problems. We exploit the basic-nonbasic partition to design novel preconditioners for iterative methods applied to these systems. A two-phase iterative method is used which switches between different preconditioners. We provide a spectral analysis for the preconditioners and illustrate their practical behaviour on medium-scale problems from the Netlib collection.

Luiz-Rafael Santos, IMECC/Unicamp (with Aurelio Oliveira, Clovis Perin, Fernando Villas-Bôas)

A polynomial optimization subproblem in interior-point methods

In this work we study a primal-dual path-following interior point method for linear programming. Our approach, based on Mehrotra's predictor-corrector methods, combines three types of directions to generate a better one by making an extensive use of real-valued polynomials on variables (α, μ, σ) , where α is the step length, μ defines a more general central path, and σ models the weight that a predictor direction should have. We develop a merit function that is a polynomial in (α, μ, σ)

and that is used as a guide to combine those directions. This merit function is subjected to polynomial constraints, which are designed to keep the next point into a good neighbourhood of the central path – a generalization of Gondzio-Colombo's symmetric neighbourhood. A polynomial optimization problem (POP) arises from this approach and its global solution, in each iteration, leads to the choice of the next direction. Different methods for solving the POP are being experimented and the computational experiments are promising.

Nonlinear programming

Thu.2.H 0112

Semidefinite and DC programming

Chair Ibraheem Alolyan, King Saud University

Ibraheem Alolyan, King Saud University

Zeros of quadratic interval polynomials

In this paper, we study the zeros of interval polynomials. We develop a method to compute all zeros of such polynomial with interval coefficients and give the characterization of the roots.

Nonsmooth optimization

Thu.2.H 1012

Policy iteration algorithms and some applications

Organizer/Chair Hasnaa Zidani, ENSTA ParisTech & Inria · Invited Session

Hasnaa Zidani, ENSTA ParisTech & Inria (with Olivier Bokanowski)

Some convergence results for the policy iterations algorithm.

In this talk, we will present some convergence results of Howard's algorithm for the resolution of equations in the form of $\min_{\alpha \in A} (B_{\alpha}x - c_{\alpha}) = 0$, where B_{α} is a matrix, c_{α} is a vector, and A is a compact set. We show a global superlinear convergence result, under a monotonicity assumption on the matrices B_{α} . An extension of Howard's algorithm for a max-min problem of the form $\max_{b \in B} \min_{\alpha \in A} (B_{\alpha,b}x - c_{\alpha,b}) = 0$ will be also proposed.

The algorithms are illustrated on the discretization of nonlinear PDEs arising in the context of mathematical finance (American option and Merton's portfolio problem), of front propagation problems, and for the double-obstacle problem, and Hamilton-Jacobi equations.

Jan Hendrik Witte, University of Oxford (with Christoph Reisinger)

Penalty methods for the solution of discrete HJB equations – continuous control and obstacle problems

We present a novel penalty approach for the numerical solution of continuously controlled HJB equations and HJB obstacle problems. Our results include estimates of the penalisation error for a class of penalty terms, and we show that variations of Newton's method can be used to obtain globally convergent iterative solvers for the penalised equations. Furthermore, we discuss under what conditions local quadratic convergence of the iterative solvers can be expected. We include numerical results demonstrating the competitiveness of our methods.

Stephane Gaubert, INRIA and CMAP, Ecole Polytechnique (with Marianne Akian, Jean Cochet-Terrasson, Sylvie Detournay)

Policy iteration algorithm for zero-sum stochastic games with mean payoff

We develop a policy iteration algorithm to solve zero-sum stochastic games with finite state, perfect information and ergodic payoff (mean payoff per turn). An initial version of this algorithm was introduced by Cochet-Terrasson and Gaubert in 2006, who assumed an exact model of the arithmetics and the finiteness of action spaces. This algorithm does not require any irreducibility assumption on the Markov chains determined by the strategies of the players. It is based on a discrete nonlinear analogue of the notion of reduction of a super-harmonic function, which ensures the convergence even in the case of degenerate iterations, in which the mean payoff is not improved. Hence, it can be applied to monotone discretizations of stationary Isaacs partial differential equations without any strong ellipticity assumption. We report examples on Isaacs equations, as well as on a discrete combinatorial game (variant of the infinity Laplacian on a graph) in which degenerate iterations do occur. We also discuss numerical issues due to ill conditioned linear problems.

Optimization in energy systems

Thu.2.MA 549

Optimization in the natural gas markets

Organizer/Chair Guillaume Erbs, GDF SUEZ · Invited Session

Guillaume Erbs, GDF SUEZ (with Romain Apparigliato)

Application of stochastic dual dynamic programming to the analysis of natural gas markets

With their liberalization, the natural gas markets constitute an increasingly complex and uncertain environment. In order to model such a system, one has to take into account the various assets that are used along the chain: production, transport (pipeline or LNG) and storage. In this presentation, we make the assumption of perfect competition and we focus on the uncertainty on assumption (i.e., we make the assumption of a risk neutral central planner).

The considered problem is a multiperiod stochastic problem with a great number of assets and periods. The stochastic dual dynamic programming algorithm (Pereira and Pinto 1991) is well suited for this kind of problems. It constructs an approximation of the Bellmann functions by sampling the uncertainty and is widely used for hydro-power systems planning for its performance in practice. We will talk about its application to a natural gas system.

Abada Ibrahim, GDF SUEZ (with Jouvét Pierre André)

A stochastic generalized Nash-Cournot model for the European gas market. The S-GMMES model.

We present a Stochastic Generalized Nash-Cournot model of the gas markets. The major gas chain players are depicted. We consider market power and the demand representation captures the fuel substitution and the fluctuation of the oil price. Long-term contracts as well as production and pipeline investments are endogenous. The model has been applied to represent the European gas market and forecast consumption, prices, production and foreign dependence till 2030. Finally, we have calculated the value of the stochastic solution.

Asgeir Tomasgard, NTNU (with Lars Hellemo, Kjetil Midthun, Adrian Werner)

Multi-stage stochastic programming for natural gas infrastructure design

We present a multi-stage stochastic model that analyzes investments in natural gas fields and infrastructure. New projects are evaluated together with existing infrastructure and planned expansions. Several uncertain factors both upstream and downstream such as reservoir volumes, the composition of the gas in new reservoirs, market demand and price levels can influence the optimal decisions. The model focuses also on the impact of the sequencing of field developments and new infrastructure on the expected security of supply. In order to analyze all these aspects in one model, we propose a novel approach to scenario trees, combining long-term and short-term uncertainty. Dimensionality and solution times of realistic investment cases from the Norwegian Continental Shelf are discussed. Experience from a parallel implementation of branch-and-fix coordination is summarized.

Optimization in energy systems

Thu.2.MA 550

Bilevel programming and housing retrofit

Chair Mark Jennings, Imperial College London

Eugene Zak, Alstom Grid Inc. (with Sami Ammari, Kwok Cheung)

Bilevel Programming for combinatorial auctions in electricity markets

In advanced electricity markets some bids and offers extend over a block of several consecutive time periods so that the block bid/offer has to be cleared entirely for all time periods comprising the block. According to a typical market rule a block bid can be cleared only if its price is not lower than the average market price. Similarly, a block offer can be cleared only if its price is not higher than the average market price. The dilemma occurs: block bids/offers selection as a primal solution cannot be properly exercised without knowing the prices as a dual solution, and the prices depend on the selection decisions. We propose a model harmonizing such complex "primal-dual" market rules. The model, based on bilevel programming, ties together the primal and dual variables so that the "primal-dual" market rules become a part of the overall model. The model is a non-linear Mixed Integer Program (MIP). We have implemented an exact algorithm to solve this model. The computational results demonstrate the adequacy of the modeling and algorithmic approaches and their practical value for several European electricity markets with combinatorial auctions.

Peter Gross, Universität Wien (with Raimund Kovacevic, Georg Pflug)

Risk averse bilevel problems in energy markets

Our work introduces risk averse bilevel problems as a special case

of stochastic bilevel problems. These problems can for example arise at the pricing of energy delivery contracts, when instead of a replication approach a game-theoretic approach to pricing is chosen. In the latter case, the exercise price set by the seller anticipates the exercise strategy of the buyer that will be triggered by this particular exercise price. The special case where constraints on the seller's risk are included in the model, we call risk averse bilevel problem. This particular type of bilevel problem where the seller's constraints depend on the buyer's exercise strategy has so far received little attention, since in general it leads to a nonconvex optimization problems where the feasible set even may be nonconnected. We demonstrate the properties and particular difficulties of this problem and present algorithms suitable for solving it. We apply an iterative solution method on some real data and investigate the numerical behavior.

Mark Jennings, Imperial College London (with David Fisk, Nilay Shah)

Optimization of technology investments and capital management in an urban energy system housing retrofit project: Use of rolling horizons in a London borough study

We consider formulations optimizing the technological and capital decisions taken when retrofitting urban energy systems at the large-scale. This study can be considered a minimum cost strategic capital management problem, incorporating a resource-task network representation of the housing stock's demand and supply side energy systems. We use real data on existing housing conditions from a London borough seeking to minimise its housing stocks's greenhouse gas emissions. We seek to answer two research questions: (i) what is the effect of rolling horizons on investments which retrofit housing technologies?, and (ii) to what degree does the abstraction of the temporally dynamic technological operations in separate LP, MILP, and MINLP formulations impact upon the optimizations's fidelity, piecewise special ordered set branching error, and processing unit solution time respectively? Initial insights suggest that expected reductions in energy demand may be adversely affected by investor attitudes to shorter time horizons. MILP formulations of housing retrofit projects may offer the best tradeoffs between fidelity/accuracy and reasonable solution times.

PDE-constrained opt. & multi-level/multi-grid meth.

Thu.2.H 0111

PDE optimization in medicine II

Organizer/Chair Anton Schiela, TU Berlin · Invited Session

Martin Frank, RWTH Aachen University (with Richard Barnard, Michael Herty)

Optimal radiotherapy treatment planning using minimum entropy models

We study the problem of finding an optimal radiotherapy treatment plan. A time-dependent Boltzmann particle transport model is used to model the interaction between radiative particles with tissue. This model allows for the modeling of inhomogeneities in the body and allows for anisotropic sources modeling distributed radiation and external beam sources. We study two optimization problems: minimizing the deviation from a spatially-dependent prescribed dose through a quadratic tracking functional; and minimizing the survival of tumor cells through the use of the linear-quadratic model of radiobiological cell response. For each problem, we derive the optimality systems. In order to solve the state and adjoint equations, we use the minimum entropy approximation; the advantages of this method are discussed. Numerical results for real patient data are presented.

Chamakuri Nagaiah, Johann Radon Institute for Computational and Applied Mathematics (RICAM) (with Karl Kunisch, Gernot Plank)

Numerical solutions for boundary control of bidomain equations in cardiac electrophysiology

The bidomain equations are widely accepted as one of the most complete descriptions of the cardiac bioelectric activity at the tissue and organ level. The model consist of a system of elliptic partial differential equations coupled with a non-linear parabolic equation of reaction-diffusion type, where the reaction term, modeling ionic transport is described by a set of ordinary differential equations. The optimal control approach is based on minimizing a properly chosen cost functional $J(v, I_e)$ depending on the extracellular current I_e as input, which must be determined in such a way that wave-fronts of transmembrane voltage v are smoothed in an optimal manner. The boundary control formulation is presented. The numerical realization of the optimality system is described in detail and numerical experiments, which demonstrate the capability of influencing and terminating reentry phenomena, are presented. We employ the parallelization techniques to enhance the solution process of the optimality system and a numerical feasibility study

of the Lagrange-Newton-Krylov method in a parallel environment will be shown.

Malik Kirchner, Zuse Institut Berlin (ZIB)

Large deformation diffeomorphic metric mapping using conforming adaptive finite elements

Automatic registration of anatomical objects is an important task in medical imaging. One crucial prerequisite is finding a pointwise mapping between different shapes.

Currents are linear functionals providing a unified description of those shapes of any positive integer dimension $m \leq d$ embedded in \mathbb{R}^d . The Large Deformation Diffeomorphic Metric Mapping (LDDMM) framework [Joshi and Miller, IEEE Transactions on Image Processing, 2000] solves the correspondence problem between them by evolving a displacement field along a velocity field.

In this talk we propose three aspects making this ODE/PDE optimization problem numerically practical. We compute the temporal propagation of m -currents using a spatially discretized velocity field on conforming adaptive finite elements. A hierarchical approach from coarse to fine lattices improves performance and robustness of our method. The adaptive refinement process is driven by some residual estimator based on the Riesz representative of shape differences.

PDE-constrained opt. & multi-level/multi-grid meth.

Thu.2.MA 415

Theory and methods for PDE-constrained optimization problems with inequalities

Organizer/Chair Michael Ulbrich, Technische Universität München - Invited Session

Francisco José Silva Alvarez, Dipartimento di Matematica "Guido Castelnuovo", La Sapienza (with Terence Bayen, Frédéric Bonnans)

Characterization of quadratic growth for strong minima in the optimal control of semi-linear elliptic equations

In this work, we are concerned with the following optimal control problem:

$$\min_u J(u) := \int_{\Omega} \ell(x, y_u(x), u(x)) dx,$$

under bounds constraints on the control u , and where y_u is the unique solution of

$$\begin{cases} -\Delta y(x) + \varphi(x, y(x), u(x)) = 0, & \text{for } x \in \Omega, \\ y(x) = 0, & \text{for } x \in \partial\Omega. \end{cases}$$

We extend to *strong solutions* classical second order analysis results, which are usually established for *weak solutions*. We mean by strong solution a control \bar{u} that satisfies:

There exists $\varepsilon > 0$ such that $J(\bar{u}) \leq J(u)$ for all u with $\|y_u - y_{\bar{u}}\| \leq \varepsilon$.

The study of strong solutions, classical in the Calculus of Variations, seems to be new in the context of the optimization of elliptic equations. Our main result is a characterization of local quadratic growth for the cost function J around a strong minimum.

Martin Weiser, Zuse Institute Berlin

Goal-oriented estimation for nonlinear optimal control problems

In optimal control problems with elliptic PDE constraints,

$$\min J(y, u) \quad \text{s.t.} \quad c(y, u) = 0,$$

the value of the cost functional is a natural quantity of interest for goal-oriented error estimation and mesh refinement. The talk will discuss the difference between the all-at-once error quantity $J(y^h, u^h) - J_{\text{opt}}$ introduced by Becker/Kapp/Rannacher and the black-box error quantity $J(y(u^h), u^h) - J_{\text{opt}}$. Both qualitative and quantitative differences will be addressed for linear-quadratic problems.

In the second part, the black-box approach will be extended to smooth nonlinear problems and will result in a novel accuracy matching for inexact Newton methods. Quantitative aspects are illustrated on numerical examples including interior point regularizations of inequality constrained problems.

Florian Kruse, Technische Universität München (with Michael Ulbrich)

An infeasible interior point method for optimal control problems with state constraints

We present an infeasible interior point method for pointwise state constrained optimal control problems with elliptic PDEs. A smoothed constraint violation functional is used to develop a self-concordant barrier approach in an infinite-dimensional setting. For the resulting algorithm we provide a detailed convergence analysis in function space. This includes a rate of convergence and a rigorous measure for the proximity of the actual iterate to both the path of minimizers and the solution

of the problem. Moreover, we report on numerical experiments to illustrate the efficiency and the mesh independence of this algorithm.

Robust optimization

Thu.2.MA 004

Multistage robustness

Organizer/Chair Ulf Lorenz, Technische Universität Darmstadt - Invited Session

Jan Wolf, Technische Universität Darmstadt (with Ulf Lorenz)

Accelerating nested Benders decomposition with game-tree search techniques to solve quantified linear programs

Quantified linear programs (QLPs) are linear programs with variables being either existentially or universally quantified. The problem is similar to two-person zero-sum games with perfect information, like, e.g., chess, where an existential and a universal player have to play against each other. At the same time, a QLP is a variant of a linear program with a polyhedral solution space. On the one hand it has strong similarities to multi-stage stochastic linear programs with variable right-hand side. On the other hand it is a special case of a multi-stage robust optimization problem where the variables that are affected by uncertainties are assumed to be fixed. In this paper we show how the problem's ambiguity of being a two-person zero-sum game, and simultaneously being a convex multistage decision problem, can be used to combine linear programming techniques with solution techniques from game theory. Therefore, we propose an extension of the Nested Benders Decomposition algorithm with two techniques that are successfully used in game-tree search – the $\alpha\beta$ -heuristic and move-ordering.

Kai Habermehl, TU Darmstadt (with Stefan Ulbrich)

Robust design of active trusses via mixed integer nonlinear semidefinite programming

This work is an extension of Ben-Tal and Nemirovski's approach on robust truss topology design to active trusses. Active trusses may use active components (e.g., piezo-actuators) to react on uncertain loads. The aim is to find a load-carrying structure with minimal worst-case compliance, when actuators may be used to react on uncertain loadings. This problem leads to a min-max-min formulation.

The approach is based on a semidefinite program formulation, which is a well-known optimization approach for robust truss topology design. By introducing actors into the model, it becomes a non-linear semidefinite program with binary variables. We use a sequential semidefinite programming approach within a branch-and-bound framework to solve these problems.

Different uncertainty sets are analyzed for the robust optimization approach – mainly polyhedral and ellipsoidal uncertainty sets. These different approaches have their specific advantages and disadvantages. A combined approach seems to be the best way to deal with active elements in robust truss topology design. Several solution methods (e.g., Cascading techniques, projection approaches) and numerical results will be presented.

Marc Goerigk, Universität Göttingen (with Emilio Carrizosa, Anita Schöbel)

A geometric approach to recovery robustness

Finding robust solutions of an optimization problem is an important issue in practice, as solutions to optimization problems may become infeasible if the exact model parameters are not known exactly. Roughly speaking, the goal in robust optimization is to find solutions which are still valid if the input data changes, thus increasing the practical applicability of optimization algorithms in real-world problems.

Various concepts on how to define robustness have been suggested. A recent model follows the idea of recovery robustness. Here, one looks for a first-stage solution which is recoverable to a feasible one for any possible scenario in the second stage. Unfortunately, finding recovery robust solutions is in many cases computationally hard.

In this talk we propose the concept of "recovery to feasibility", a variation of recovery robustness based on geometric ideas, that is applicable for a wide range of problems. In particular, an optimal solution can be determined efficiently for linear programming problems and problems with quasiconvex constraints for different types of uncertainties. For more complex settings reduction approaches are proposed.

Sparse optimization & compressed sensing

Thu.2.H 1028

Nonconvex sparse optimization

Organizer/Chair Wotao Yin, Rice University - Invited Session

Zaiwen Wen, Shanghai Jiaotong University

Alternating direction augmented Lagrangian methods for a few nonconvex problems

Recently, the alternating direction augmented Lagrangian methods

(ADM) have been widely used in convex optimization. In this talk, we show that ADM can also be quite efficient for solving nonconvex problems such as phase retrieval problem in X-ray diffractive imaging and an integer programming problem in portfolio optimization.

Francesco Solombrino, RICAM (with Massimo Fornasier)

Linearly constrained nonsmooth and nonconvex minimization

Motivated by variational models in continuum mechanics, we introduce a novel algorithm for performing nonsmooth and nonconvex minimizations with linear constraints. We show how this algorithm is actually a natural generalization of well-known non-stationary augmented Lagrangian methods for convex optimization. The relevant features of this approach are its applicability to a large variety of nonsmooth and nonconvex objective functions, its guaranteed global convergence to critical points of the objective energy, and its simplicity of implementation. In fact, the algorithm results in a nested double loop iteration, where in the inner loop an augmented Lagrangian algorithm performs an adaptive finite number of iterations on a fixed quadratic and strictly convex perturbation of the objective energy, while the external loop performs an adaptation of the quadratic perturbation. To show the versatility of this new algorithm, we exemplify how it can be easily used for computing critical points in inverse free-discontinuity variational models, such as the Mumford-Shah functional, and, by doing so, we also derive and analyze new iterative thresholding algorithms.

Ming-Jun Lai, University of Georgia (with Louis Yang)

On the Schatten p -quasi-norm minimization for low rank matrix recovery

We provide a sufficient condition to show when the Schatten p -quasi-norm minimization can be used for matrix completion to recover the rank minimal matrix. The condition is given in terms of the restricted isometry property in the matrix version. More precisely, when the restricted isometry constant $\delta_{2r} < 1$, there exists a real number $\rho_0 < 1$ such that any solution of the ℓ_p minimization is the minimal rank solution for $\rho \leq \rho_0$.

Stochastic optimization

Thu.2.MA 141

Two-stage stochastic programming and beyond

Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen · Invited Session

Dimitri Drapkin, University of Duisburg-Essen (with Rüdiger Schultz)

Decomposition methods for optimization problems with stochastic order constraints induced by linear recourse

We develop linear programming equivalents for two-stage stochastic optimization models with linear recourse and dominance constraints of first and second order. In the favourable case, where only continuous variables are present in the second stage, cutting-plane decomposition algorithms are proposed and discussed along with the computational results.

Charlotte Henkel, University of Duisburg-Essen (with Rüdiger Schultz)

Some remarks on linear stochastic bilevel programs

Compared to linear stochastic two-stage programs, linear stochastic bilevel problems (LSBP) exhibit a strongly increased complexity. Starting from a deterministic linear bilevel problem, we derive structural properties for LSBPs using state-of-the-art parametric optimization techniques. As an outcome, we obtain rather weak analytical results. This significantly affects risk measures and solution algorithms for this kind of problem. We emphasize our results by instructive examples.

Nadine Wollenberg, University of Duisburg-Essen (with Uwe Clausen, Rüdiger Schultz, Sascha Wohlgemuth)

Stochastic vehicle routing in forwarding agencies

The performance of forwarding agencies handling less-than-truckload freight is mainly influenced by uncertainty in terms of customer demand and travel times. In the talk we discuss two-stage stochastic integer programs with different objective functions such as minimizing the total travel time or minimizing the number of vehicles used for a feasible routing. For the ranking of the resulting stochastic cost profiles we employ different stochastic quality measures leading to risk neutral models and those quantifying some aversion against risk. Algorithmically we rely on scenario decomposition achieved by Lagrangean relaxation of nonanticipativity. Some first computational experiments with realistic problem instances relevant for forwarding agencies in the Ruhr Area are presented.

Stochastic optimization

Thu.2.MA 144

Large-scale and multi-stage stochastic optimization

Chair Alois Pichler, University of Vienna

Anna Timonina, University of Vienna

Multi-stage stochastic optimisation and approximations with applications

Multi-stage stochastic optimization problems play a very important role in management of financial portfolios, energy production, insurance portfolios etc. The exact analytical solution for such problems can be found only in very exceptional cases and the necessity of an approximation arises immediately. The aim of this research is to study the approximation of the stochastic process by the probability valued finite tree. We use the concept of nested distribution to describe the information structure keeping the setup purely distributional and the concept of nested distance to measure the distance between nested distributions and to quantify the quality of approximation. We introduce the algorithm for calculating the nested distance between tree and stochastic process given by its distribution. Minimization of this distance can lead to the new method for generating values from some specific distribution along with Monte Carlo generating and Optimal Quantization. The main advantage of this algorithm is that it takes into account conditional distributions at each stage, that allows to approximate a large class of processes.

Jose Nino-Mora, Carlos III University of Madrid (Q-2818029-G)

Sufficient indexability conditions for real-state restless bandit projects via infinite-dimensional LP-based partial conservation laws

The multiarmed restless bandit (RB) problem concerns the optimal dynamic allocation of a shared resource to multiple stochastic projects, modeled as RBs, i.e., binary-action (active/passive) Markov decision processes. Although the problem is generally intractable, a unified approach to construct heuristic policies based on the Whittle priority index, or extensions thereof, has been shown to perform well in a variety of models. Deploying such an approach requires to establish the indexability (i.e., existence of the index) for the constituent RBs, and to evaluate the index numerically. This work presents the first general sufficient conditions for indexability of real-state RBs, motivated by applications that have drawn recent research attention. The conditions are based on an infinite-dimensional LP extension of partial conservation laws, an approach formerly introduced by the author to provide sufficient indexability conditions for discrete-state RBs. The approach further provides a practical means to evaluate the index. Applications will be discussed.

Alois Pichler, University of Vienna

Approximation of stochastic processes

We deal with extremely large scale and high dimensional optimization, where managerial decisions are allowed at consecutive instants of time. Scenarios, reflecting future states of the world, are considered random. It is well known how to deal with these types of stochastic optimization problems with an expectation in the objective, but we want to additionally address risk. The newly introduced notion of a process distance (Pflug) allows quantifying approximations. We address approximations, which allow reasonable computation times and give viable bounds in comparison to the original problem. The results are general enough to involve risk measures, which (historically) appeared first in finance and insurance. Finally the approximating processes can be improved by different means to improve their approximating quality.

Telecommunications & networks

Thu.2.H 3002

Network clustering

Organizer/Chair Sergiy Butenko, Texas A&M University · Invited Session

Michael Ovelgönne, University of Maryland (with Andreas Geyer-Schulz)

Ensemble learning for combinatorial optimization: Modularity maximization and beyond

Modularity maximization is the NP-hard problem of identifying a graph partition with a maximal value of the quality measure modularity. Modularity maximization is a well-studied problem in the area of community detection in networks and attracted much attention in computer science as well as physics. A vast number of algorithms have been proposed for this problem. The core groups graph clustering (CGGC) scheme is an ensemble learning clustering method with very high optimization quality. This method combines the local solutions of several base algorithms to form a good start solution (core groups) for the final algorithm. Especially iteratively finding good restart points showed to result in very good optimization quality. We will draw an analogy between the discrete problem of modularity maximization with nonlinear optimization in finite dimensions. We will show that core groups

are the discrete counter-parts of saddle-points and that they constitute good restart points for greedy algorithms. While we developed the CGGC scheme for graph clustering, we believe this optimization scheme can be applied to many other combinatorial optimization problems as well.

Andrea Schumm, Karlsruhe Institute of Technology (with Robert Görke, Dorothea Wagner)

Experiments on density-constrained graph clustering

Clustering a graph means identifying internally dense subgraphs which are only sparsely interconnected. Formalizations of this notion lead to measures that quantify the quality of a clustering and to algorithms that actually find clusterings. Since, most generally, corresponding optimization problems are hard, heuristic clustering algorithms are used in practice, or other approaches which are not based on an objective function. In this work we conduct a comprehensive experimental evaluation of the qualitative behavior of greedy bottom-up heuristics driven by cut-based objectives and constrained by intracluster density, using both real-world data and artificial instances. Our study documents that a greedy strategy based on local-movement is superior to one based on merging. We further reveal that the former approach generally outperforms alternative setups and reference algorithms from the literature in terms of its own objective, while a modularity-based algorithm competes surprisingly well. Finally, we exhibit which combinations of cut-based inter- and intracluster measures are suitable for identifying a hidden reference clustering in synthetic random graphs.

Cong Sun, Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Low complexity interference alignment algorithms for desired signal power maximization problem of MIMO channels

The Interference alignment technique is newly brought into wireless communication to improve the communication capacity. For a K-user MIMO interference channel, we propose a low complexity interference alignment algorithm to solve the desired signal power maximization problem, which is a nonconvex complex matrix optimization problem. First we use a Courant penalty function technique to combine the objective function as desired signal power with the interference constraint, leaving only the orthogonal constraints. By introducing the Householder transformation, the matrix problem turns into vector optimization problem. Applying the alternating direction method and the two-dimensional subspace method, the computational complexity of the algorithm is greatly reduced. To overcome the disadvantage of this algorithm to converge slowly around the local optimal solution, it is combined with a higher complexity algorithm which helps to perfectly eliminate interference and satisfy the original constraints. Simulations show that compared to the existed algorithms, the hybrid algorithm needs less computing time and achieves good performance.

Telecommunications & networks

Thu.2.H 3503

Paths, trees and flows

Chair Álvaro Franco, Instituto de Matemática e Estatística - Universidade de São Paulo

Álvaro Franco, Instituto de Matemática e Estatística - Universidade de São Paulo (with Carlos Ferreira)

A new linear time algorithm to construct dominator trees of reducible flow graphs

A flow graph $G = (V, E, r)$ is a directed graph, where r is a vertex in G that reaches any vertex v in G . A vertex w dominates vertex v if any path from r to v passes through w . A vertex w is the immediate dominator of v ($\text{id}(v) = w$) if w dominates v and any dominator of v dominates w . It is well known that for each vertex $v \neq r$ there is a single vertex w that dominates immediately v . The graph $T = (V, E')$, where $E' = \{(\text{id}(v), v) : v \in V \setminus \{r\}\}$ is a rooted tree (root in r) called dominator tree of G . Sophisticated algorithms have been proposed to construct a dominator tree of a flow graph (e.g., Georgiadis and Tarjan, 2004). Even if the flow graph is reducible the algorithms existing are hard to implement (e.g., the linear implementation of Ramalingam and Reps algorithm, 1994). We develop a linear time algorithm to construct a dominator tree of G (reducible). It uses simpler data structures to determine whether there are internally vertex-disjoint paths from r to u and from r to v , for all pairs of vertices u, v in G , and to answer lowest common ancestor queries in a depth-first spanning tree of G .

Elena Fernandez, Technical University of Catalonia (with Carlos Luna Mota, Gerhard Reinelt)

A compact formulation for the optimum communication spanning tree problem

The optimum communication spanning tree problem (OCSTP) is a difficult combinatorial optimization problem with multiple applications in telecommunications and transportation. In the OCSTP communication requirements r_{ij} exist between pairs of nodes, and the communication cost between i, j , over a given spanning tree T , depends on r_{ij} and on the distance on T between i and j . Looking for a balance between construction and communication costs, the objective in the OCST is to

find a spanning tree of minimum total communication cost. We present a formulation with two index decision variables, which models any partial order as a rooted tree. We further specialize the above formulation to model the OCSTP, by incorporating additional decision variables to represent the distance on the tree between pairs of nodes. We discuss some properties and reinforcements of the formulation, which is compared with a classical formulation with four index variables. Some numerical computational results are presented and analyzed.

Per Olav Lindberg, KTH Royal Inst. Technology (with Johan Holmgren)

Updating shortest path subproblem solutions in large scale optimization

In many large scale optimization applications, one repetitively solves shortest path (SP) subproblems, with slowly varying and possibly converging characteristics. In such situations, it's worthwhile to update the subproblem solutions, rather than solving from scratch. In this paper we describe simplex-like updating of the SP trees, using thread labels. We suggest three improvements to the standard approach:

1. Thread following link scan,
2. bucketed link scan, and
3. acyclic thread

In thread following link scan, we only need a single traversal of the thread to find all entering links. In the bucketed link scan, we do partial pricing. Instead of scanning all arcs, we keep and update a "bucket" of "promising" links. This gives suboptimal subproblem solutions, but speeds up the convergence. Every now and then, we do a complete scan, and then add and delete links to/from the buckets. In acyclic thread, the thread is modified to scan an acyclic graph, i.e., the graph of bucket links. The acyclic thread scans the nodes in the graph-induced order, and does not need to be updated, unless new arcs are added. We will present computational results for small to large scale traffic assignment problems.

Variational analysis

Thu.2.H 2035

Stability of constraint systems

Organizer/Chair René Henrion, Weierstrass Institute Berlin · Invited Session

Alexey Izmailov, Moscow State University (with Alexey Kurennoy)

Strong regularity and abstract Newton schemes for nonsmooth generalized equations

We suggest the inverse function theorem for generalized equations, unifying Robinson's theorem for strongly regular generalized equations and Clarke's inverse function theorem for equations with locally Lipschitzian mappings. This theorem is further applied in the context of very general Newton schemes, covering, among others, some methods which are usually not regarded as Newtonian. In particular, we derive new local convergence results for the augmented Lagrangian methods applied to optimization problems with locally Lipschitzian derivatives.

René Henrion, Weierstrass Institute Berlin (with Alexander Kruger, Jiri Outrata, Thomas Surowiec)

On (co-)derivatives of the solution map to a class of generalized equations

This talk is devoted to the computation of (co-)derivatives of solution maps associated with a frequently arising class of generalized equations. The constraint sets are given by (not necessarily convex) inequalities for which we do not assume the linear independence of gradients. On the basis of the obtained generalized derivatives, new optimality conditions for a class of mathematical programs with equilibrium constraints are derived, and a workable characterization of the isolated calmness of the considered solution map is provided. The results are illustrated by means of examples.

Marco A. Lopez, Alicante University (with A. Daniilidis, M. A. Goberna, R. Lucchetti)

Lower semicontinuity of the feasible set mapping of linear systems relative to their domains

The talk deals with stability properties of the feasible set of linear inequality systems having a finite number of variables and an arbitrary number of constraints. Several types of perturbations preserving consistency are considered, affecting respectively, all of the data, the left-hand side data, or the right-hand side coefficients. Our analysis is focussed on (lower semi-)continuity properties of the feasible mapping confined to its effective domain, dimensional stability of the images and relations with Slater-type conditions. The results presented here are established in a joint paper with A. Daniilidis, M. A. Goberna, and R. Lucchetti.

Variational analysis

Thu.2.H 2051

Variational analysis of optimal value functions and set-valued mappings with applications

Organizer/Chair Mau Nam Nguyen, University of Texas-Pan American · Invited Session

Messaoud Bounkhel, King Saud University (with Chong Li)

Regularity concepts of perturbed distance functions at points outside of the set in Banach spaces

In this talk I will present some new results on the (Fréchet, proximal, Clarke, Mordukhovich) subdifferential of the perturbed distance function $d_S^l(\cdot)$ determined by a closed subset S and a Lipschitz function $J(\cdot)$. Using these results, I will establish some important relationships between the regularity of the set and the perturbed distance function at points outside of S in arbitrary Banach space.

Sangho Kum, Chungbuk National University

A geometric mean of parameterized arithmetic and harmonic means of convex functions

Recently Bauschke et al. [2008] introduced a new notion of proximal average, and studied this subject systemically from various viewpoints. The proximal average can be an attractive and powerful alternative to the classical arithmetic and epigraphical averages in the context of convex analysis and optimization problems. The present work aims at providing a further development of the proximal average. For that purpose, exploiting the geometric mean of convex functions by Atteia and Ras-souli [2001], we develop a new algorithmic self-dual operator for convex functions termed “the geometric mean of parameterized arithmetic and harmonic means of convex functions”, and investigate its essential properties.

Nguyen Dong Yen, Institute of Mathematics, Vietnam Academy of Science and Technology (with Gue Myung Lee)

Coderivatives of a Karush-Kuhn-Tucker point set map and applications

The trust-region subproblem corresponding to the triple $\{A, b, \alpha\}$, where $A \in \mathbb{R}^{n \times n}$ is a symmetric matrix, $b \in \mathbb{R}^n$ a given vector, and $\alpha > 0$ a real number, is the optimization problem

$$\min \left\{ f(x) := \frac{1}{2} x^T A x + b^T x : \|x\|^2 \leq \alpha^2 \right\}. \quad (P)$$

One often encounters with (P) in the development of trust-region methods for nonlinear programs. Since the feasible region of (P) is a convex compact set with an infinite number of extreme points, the structure of its solution set (resp. of its Karush-Kuhn-Tucker point set) is quite different from that of quadratic programs with linear constraints. By using some tools from Variational Analysis, this paper investigates the stability of (P) with respect to the perturbations of all the three components of its data set $\{A, b, \alpha\}$.

Variational analysis

Thu.2.MA 649

Variational methods in inverse problems

Organizer/Chair Elena Resmerita, Alpen-Adria University · Invited Session

Esther Klann, University of Linz

A Mumford-Shah type approach for tomography data

We present a Mumford-Shah-type approach for the simultaneous reconstruction and segmentation of a function from its tomography data (Radon transform). The sought-after function is modeled as a piecewise constant function. Hence, it consists of n sets Ω_i and the corresponding values c_i . The sets and values together with their number are found as minimizers of a Mumford-Shah-type functional. We present a level-set based minimization algorithm for this functional as well as theoretical results regarding the existence of minimizers, stability and regularization properties. We also present numerical results for tomography problems with limited data (limited angle, region of interest and electron tomography).

Mihaela Pricop-Jeckstadt, Leibniz Institute for Farm Animal Biology (with Norbert Reinsch)

Genomic selection and iterative regularization methods

In genomic selection it is expected that genetic information contributes to selection for difficult traits like traits with low heritability, traits which are hard to measure or sex limited traits. The availability of dense markers covering the whole genome leads to genomic methods aiming for estimating the effect of each of the available single nucleotide polymorphisms. Hence, we propose a semiparametric method and an iterative regularization approach for high-dimensional but small sample-sized data. Numerical challenges like model selection, the estimation

of the predictive ability and the choice of the regularization parameter are discussed and illustrated by simulated and real data examples.

Christiane Pöschl, Alpen-Adria Universität Klagenfurt (with Vicent Caselles, Matteo Novaga)

TV-denoising and evolution of sets

Let $S \subset \mathbb{R}^2$ be the union of two convex sets with smooth boundary. We connect the levelsets of the minimizers u_λ of

$$\frac{1}{2} \|u - \chi_S\|_{L^2}^2 + \lambda \|u\|_{TV} \quad (1)$$

to the minimizers of a (simpler) set-minimization problem in order to obtain a geometrical characterization of the levelsets of u_λ . Moreover, we calculate explicit minimizers of (1), when S is the union of two non-intersecting circles/squares, using simple morphological operators. We also show how to construct the solutions for the more general case when S is nonconvex, starshaped set.

Approximation & online algorithms

Thu.3.H 3010

Online algorithms

Organizer/Chair Lisa Fleischer, Dartmouth College · Invited Session

Aleksander Madry, EPFL (with Nikhil Bansal, Naor Buchbinder, Joseph Naor)

A polylogarithmic-competitive algorithm for the k -server problem

In this talk, we will consider one of the fundamental problems in online optimization: the k -server problem. This problem captures many online scenarios – in particular, the widely studied caching problem – and is considered by many to be the “holy grail” problem of the field.

We will present a new randomized algorithm for the k -server problem that is the first online algorithm for this problem that achieves polylogarithmic competitiveness.

Umang Bhaskar, Dartmouth College (with Lisa Fleischer)

Online mixed packing and covering

In many problems, the inputs arrive over time, and must be dealt with irrevocably when they arrive. Such problems are *online* problems. A common method of solving online problems is to first solve the corresponding linear program online, and then round the fractional solution obtained. We give algorithms for solving mixed packing and covering linear programs, when the covering constraints arrive online. No prior sublinear competitive algorithms are known for this problem. We give the first such – a polylogarithmic-competitive algorithm for mixed packing and covering online. We also show a nearly tight lower bound.

We apply our techniques to solve two online fixed-charge problems with congestion, motivated by applications in machine scheduling and facility location. The linear program for these problems is more complicated than mixed packing and covering, and presents unique challenges. We show that our techniques combined with a randomized rounding procedure give polylogarithmic-competitive integral solutions. These problems generalize online set-cover, for which there is a polylogarithmic lower bound. Hence, our results are close to tight.

Vahab Mirrokni, Google Research NYC (with Shayan Oveisgharan, Morteza Zadimoghaddam)

Simultaneous adversarial and stochastic approximations for budgeted allocation problems

We study the problem of simultaneous approximations for the adversarial and stochastic online budgeted allocation problem: Consider a bipartite graph $G = (X, Y, E)$. When a node of X arrives online, the algorithm can match it to a neighbor in Y . The goal is to maximize the weight of the matching, while respecting the capacities. We seek algorithms that achieve very good competitive ratio on average while achieving an optimal ratio $1 - 1/e$ in the worst case. For unweighted graphs, under some mild assumptions, we show an algorithm that achieves a competitive ratio of $1 - \epsilon$ in the random permutation model. For weighted graphs, however, we prove this is not possible; we show that no online algorithm that achieves an approximation factor of $1 - 1/e$ for the worst case inputs may achieve an average approximation factor better than 97.6% for random inputs. In light of this hardness result, we aim to design algorithms with improved approximation ratios in the random arrival model while getting a $1 - 1/e$ in the worst case.

Combinatorial optimization

Thu.3.H 3004

Optimization methods for geometric problems

Organizers/Chairs Sándor Fekete, TU Braunschweig; Alexander Krölller, TU Braunschweig · Invited Session

Dan Halperin, Tel Aviv University

Multi-objective path optimization in motion planning: From the particular to the general

When planning collision-free paths for mobile objects (robots or other creatures) in environments cluttered with obstacles, it is often desirable to simultaneously consider several path-quality criteria. We start with a combination of criteria, which is commonplace in this setting: length and clearance. Namely, we wish that the path will be short and the moving object will be well away from the obstacles. We review several planning techniques specifically tailored to optimizing this combination. We then move on to a general optimization technique that can simultaneously address a large variety of objectives and does not assume any specific path-planning approach. It is based on a simple path-hybridization method, it is easy to implement, and it has proved itself highly effective for a wide range of problems, as we shall demonstrate.

Cid de Souza, University of Campinas (with Pedro de Rezende, Davi Tozoni)

Towards solving to optimality the art gallery with point-guards problem

We present our progress towards the development of an exact and effective algorithm to solve the NP-hard art gallery with point-guards problem (AGPG). A set of points is said to cover a polygon P if the union of their visibility polygons is P . In AGPG, one seeks a minimum-sized set of points in P that covers P . Despite its theoretical complexity, we give experimental evidence that AGPG can be solved to proven optimality even for large sized instances of a thousand vertices. To this end, we developed an algorithm which iteratively produces lower and upper bounds on the number of guards needed to cover P . These bounds are computed via integer programming models and rely on a theoretical result showing that for a finite set W of witnesses in P there exists an optimal solution covering W for which the guards belong to a well-defined set of points whose size is polynomial in $|W|$. We tested this algorithm on a benchmark composed of several classes of polygons of various sizes, all of which obtained from the literature. Our algorithm solves most of these instances in only tens of minutes in a standard desktop computer.

Alexander Krölller, TU Braunschweig (with Tobias Baumgartner, Sándor Fekete, Mahdi Moeini, Christiane Schmidt)

Practical solutions and bounds for art gallery problems

The classical Art gallery problem asks for the minimum number of guards that achieve visibility coverage of a given polygon. It is known to be NP-hard, even for very restricted and discrete special cases. Even though the it has been extensively studied in almost 40 years, practical algorithms to find optimal solutions or almost-optimal bounds are not known. We present a primal-dual algorithm based on mathematical programming, which provides lower bounds on the necessary number of guards and – in case of convergence and integrality – ends with an optimal solution. It has been implemented and extensively tested on different classes of polygons; experimental results will be discussed. Additionally we show how to extend the procedure to practical applications of the Art Gallery Problem. These occur in laser scanning of buildings, but come with additional constraints - such as limited viewing range and loss in quality over distances.

Combinatorial optimization

Thu.3.H 3005

Recent advances in matching algorithms

Organizer/Chair Piotr Sankowski, University of Warsaw · Invited Session

Manoj Gupta, IIT Delhi (with Surender Baswana, Sandeep Sen)

Fully dynamic maximal matching in $O(\log n)$ update time

We present an algorithm for maintaining maximal matching in a graph under addition and deletion of edges. Our data structure is randomized that takes $O(\log n)$ expected amortized time for each edge update where n is the number of vertices in the graph. While there is a trivial $O(n)$ algorithm for edge update, the previous best known result for this problem for a graph with n vertices and m edges is $O((n+m)^{0.7072})$ which is sub-linear only for a sparse graph. For the related problem of maximum matching, Onak and Rubinfeld designed a randomized data structure that achieves $O(\log^2 n)$ amortized time for each update for maintaining a c -approximate maximum matching for some large constant c . In contrast, we can maintain a factor two approximate maximum matching in $O(\log n)$ expected time per update as a direct corollary of the maximal matching scheme. This in turn also

implies a two approximate vertex cover maintenance scheme that takes $O(\log n)$ expected time per update.

Chien-Chung Huang, Humboldt-University (with Telikepalli Kavitha)

Efficient algorithms for maximum weight matchings in general graphs with small edge weights

Let $G = (V, E)$ be a graph with positive integral edge weights. Our problem is to find a matching of maximum weight in G . We present a simple iterative algorithm for this problem that uses a maximum cardinality matching algorithm as a subroutine. Using the current fastest maximum cardinality matching algorithms, we solve the maximum weight matching problem in $O(W\sqrt{nm} \log_b(n^2/m))$ time, or in $O(Wn^w)$ time with high probability, where $n = |V|$, $m = |E|$, W is the largest edge weight, and $w < 2.376$ is the exponent of matrix multiplication. In relatively dense graphs, our algorithm performs better than all existing algorithms with $W = o(\log^{1.5} n)$. Our technique hinges on exploiting Edmonds' matching polytope and its dual.

Mohammad Mahdian, Google (with Qiqi Yan)

Online bipartite matching with random arrivals: An approach based on strongly factor-revealing LPs

Karp, Vazirani, and Vazirani show that a simple ranking algorithm achieves a competitive ratio of $1 - 1/e$ for the online bipartite matching problem in the standard adversarial model. Their result also implies that in the random arrivals model defined by Goel and Mehta, where the online nodes arrive in a random order, a simple greedy algorithm achieves a competitive ratio of $1 - 1/e$. In this paper, we study the ranking algorithm in the random arrivals model, and show that it has a competitive ratio of at least 0.696, beating the $1 - 1/e = 0.632$ barrier in the adversarial model. Our analysis has two main steps. First, we exploit properties of the ranking algorithm to derive a family of factor-revealing linear programs (LPs). Second, to obtain a good lower bound on the optimal values of all these LPs and hence on the competitive ratio of the algorithm, we derive a family of modified LPs such that the optimal value of any single one of these LPs is a lower bound on the competitive ratio of the algorithm. This enables us to leverage the power of computer LP solvers to solve for large instances of the new LPs to establish bounds that would otherwise be difficult to attain by human analysis.

Combinatorial optimization

Thu.3.H 3008

Discrete structures and algorithms III

Organizer/Chair Satoru Fujishige, Kyoto University · Invited Session

Yusuke Kobayashi, University of Tokyo (with Xin Yin)

An algorithm for finding a maximum t -matching excluding complete partite subgraphs

For an integer t and a fixed graph H , we consider the problem of finding a maximum t -matching not containing H as a subgraph, which we call the H -free t -matching problem. This problem is a generalization of the problem of finding a maximum 2-matching with no short cycles, which has been well-studied as a natural relaxation of the Hamiltonian circuit problem. When H is a complete graph K_{t+1} or a complete bipartite graph $K_{t,t}$, in 2010, Bérczi and Végh gave a polynomial-time algorithm for the H -free t -matching problem in simple graphs with maximum degree at most $t + 1$. Our main contribution is to extend this result to the case when H is a t -regular complete partite graph. We also show that the problem is NP-complete when H is a connected t -regular graph that is not complete partite. Since it is known that, for a connected t -regular graph H , the degree sequences of all H -free t -matchings in a graph form a jump system if and only if H is a complete partite graph, our results show that the polynomial-time solvability of the H -free t -matching problem is consistent with this condition.

Shin-Ichi Tanigawa, Kyoto University (with Naoki Katoh)

Rooted-tree decompositions with matroid constraints and the infinitesimal rigidity of frameworks with boundaries

As an extension of a classical tree-partition problem, we consider decompositions of graphs into edge-disjoint (rooted-)trees with an additional matroid constraint. Specifically, suppose we are given a graph $G = (V, E)$, a multiset $R = \{r_1, \dots, r_t\}$ of vertices in V , and a matroid \mathcal{M} on R . We prove a necessary and sufficient condition for G to be decomposed into t edge-disjoint subgraphs $G_1 = (V_1, T_1), \dots, G_t = (V_t, T_t)$ such that (i) for each i , G_i is a tree with $r_i \in V_i$, and (ii) for each $v \in V$, the multiset $\{r_i \in R \mid v \in V_i\}$ is a base of \mathcal{M} . If \mathcal{M} is a free matroid, this is a decomposition into t edge-disjoint spanning trees; thus, our result is a proper extension of Nash-Williams' tree-partition theorem.

Such a matroid constraint is motivated by combinatorial rigidity theory. As a direct application of our decomposition theorem, we present characterizations of the infinitesimal rigidity of frameworks with non-generic "boundary", which extend classical Laman's theorem

for generic 2-rigidity of bar-joint frameworks and Tay's theorem for generic d -rigidity of body-bar frameworks.

Kiyohito Nagano, University of Tokyo (with Kazuyuki Aihara, Yoshinobu Kawahara)

Size-constrained submodular minimization through minimum norm base

A number of combinatorial optimization problems in machine learning can be described as the problem of minimizing a submodular function. It is known that the unconstrained submodular minimization problem can be solved in strongly polynomial time. However, additional constraints make the problem intractable in many settings. In this paper, we discuss the submodular minimization under a size constraint, which is NP-hard, and generalizes the densest subgraph problem and the uniform graph partitioning problem. Because of NP-hardness, it is difficult to compute an optimal solution even for a prescribed size constraint. In our approach, we do not give approximation algorithms. Instead, the proposed algorithm computes optimal solutions for some of possible size constraints in polynomial time. Our algorithm utilizes the basic polyhedral theory associated with submodular functions. Additionally, we evaluate the performance of the proposed algorithm through computational experiments.

Combinatorial optimization

Thu.3.H 3012

Arborescences

Chair Attila Bernáth, Warsaw University

Attila Bernáth, Warsaw University (with Gyula Pap)

Covering minimum cost arborescences

Given a digraph $D = (V, A)$ with a designated root node $r \in V$ and arc-costs $c : A \rightarrow \mathbb{R}$, we consider the problem of finding a minimum cardinality subset H of the arc set A such that H intersects every minimum c -cost r -arborescence. This problem is a special case of covering minimum cost common bases of two matroids, which is NP-complete even if the two matroids coincide, and the costs are all equal to 1. On the other hand we show that this special case is polynomially solvable: we give a polynomial algorithm for finding such an arc set H . The algorithm solves a weighted version as well, in which a nonnegative weight function $w : A \rightarrow \mathbb{R}_+$ is also given, and we want to find a subset H of the arc set such that H intersects every minimum c -cost r -arborescence, and $w(H)$ is minimum.

Mario Leston-Rey, Instituto de Matemática e Estatística da Universidade de São Paulo (with Yoshiko Wakabayashi)

Packing entering sets in kernel systems

In 1998, H. N. Gabow and K. S. Manu showed a strongly polynomial time algorithm to obtain – in a capacitated digraph with m arcs and n edges – a maximum integral packing of at most $m+n-2$ arborescences. We extend their result and show that, in the more general framework of packing entering sets in kernel systems, due to A. Frank, an integral packing of size at most m can be computed in strongly polynomial time.

Mikael CaU, Linköping University (with Daniel Karch)

A polyhedral analysis of a unique shortest path routing polytope

Consider a strongly connected digraph and two spanning arborescences. The arborescences form a unique shortest path system (USPS) if there is a vector of arc costs that simultaneously yields the arborescences as unique shortest path arborescences. USPSs correspond to the bases of an independence system. We characterize a large class of facet defining rank inequalities for the associated polytope. In particular, these facets can be obtained by sequential lifting of circuit inequalities. Given a circuit inequality, we determine the facet induced by an arbitrary lifting order.

Combinatorial optimization

Thu.3.H 3013

Scheduling and network flows over time

Organizer/Chair Martin Skutella, TU Berlin · Invited Session

Alberto Marchetti-Spaccamela, Sapienza University of Rome (with Leah Epstein, Asaf Levin, Nicole Megow, Julian Mestre, Martin Skutella, Leen Stougie)

Universal sequencing on an unreliable machine

We consider scheduling on an unreliable machine that may experience unexpected changes in processing speed or even full breakdowns. Our objective is to minimize the sum of weighted completion times for any non-decreasing, non-negative, differentiable cost function $f(C_j)$. We aim for a universal solution that performs well without adaptation for all cost functions for any possible machine behavior.

We design a deterministic algorithm that finds a universal scheduling sequence with a solution value within four times the value of an optimal clairvoyant algorithm that knows the machine behavior in advance. A randomized version of this algorithm attains in expectation a ratio of e . We show that both performance guarantees are best possible for any unbounded cost function.

When jobs have individual release dates, the situation changes drastically. Even if all weights are equal, there are instances for which any universal solution is a factor of $O(\log n / \log \log n)$ worse than an optimal sequence for any unbounded cost function. If the processing time of each job is proportional to its weight we present a non-trivial algorithm with a worst case of 5.

Martin Groß, TU Berlin (with Jan-Philipp Kappmeier, Daniel Schmidt, Melanie Schmidt)

Approximating earliest arrival flows in arbitrary networks

The earliest arrival flow problem is motivated by evacuation planning. It consists of computing a flow over time in a network with supplies and demands, such that the satisfied demands are maximum at every point in time. For a single source and sink, the existence of such flows has been shown by Gale [1959]. For multiple sources and a single sink the existence follows from work of Minieka [1973] and an exact algorithm has been presented by Baumann and Skutella [FOCS '06]. If multiple sinks exist, it is known that earliest arrival flows do not exist in general.

We address the open question of approximating earliest arrival flows by time or flow-value in arbitrary networks and show the first constructive results for them. We give tight bounds for the best possible approximation factor in most cases. In particular, we show that there is always a 2-flow-value approximation of earliest arrival flows and that no better approximation factor is possible in general. Furthermore, we describe an FPTAS for computing the best possible approximation factor along with the corresponding flow for any given instance (which might be better than 2).

Jan-Philipp Kappmeier, TU Berlin (with Sandro Bosio, Jannik Matuschke, Britta Peis, Martin Skutella)

Flows over time with negative transit times and arc release dates

A common generalization of the classical network flow setting are network flows over time. In contrast to the classical model, here a notion of time is incorporated that represents the time needed to travel over an arc. We present two generalizations of the maximum flow over time problem, one which allows to use negative transit times on arcs, and the other with arc release dates. In contrast to the standard maximum flow over time problem, the computational tractability of either of the generalizations depends on the possibility of flow storage at intermediate nodes. Both problems can be solved in polynomial time by reduction to the quickest transshipment problem if storage at intermediate nodes is allowed. However, if storage is forbidden, both problems are weakly NP-hard. The generalizations can both be used to answer questions on a bipartite matching over time problem, which is a generalization of the classical matching problem also incorporating a notion of time.

Complementarity & variational inequalities

Thu.3.MA 313

Algorithms for complementarity and related problems I

Chair Walter Morris, George Mason University

Artur Pogosyan, Moscow State University (with Alexey Izmailov, Mikhail Solodov)

Semismooth Newton-type methods for lifted mathematical programs with complementarity constraints

We consider a reformulation of mathematical programs with complementarity constraints, where by introducing an artificial variable the constraints are converted into equalities which are once but not twice differentiable. This approach can be regarded as a development of the lifted reformulation of complementarity constraints proposed earlier by O.Stein. We show that the Lagrange optimality system of such a reformulation is semismooth and BD -regular at the solution under reasonable assumptions. Thus, fast local convergence can be obtained by applying the semismooth Newton method. Moreover, it turns out that the squared residual of the Lagrange system is continuously differentiable (even though the system itself is not), which opens the way for a natural globalization of the local algorithm. However, from the practical viewpoint, it seems more promising to use a non-smooth exact penalty function instead of the squared residual of the Lagrange system which leads to the semismooth sequential quadratic programming method. Preliminary numerical results for problems from MacMPEC test collection demonstrate that the approach is very promising.

Evgeny Uskov, Moscow State University (with Alexey Izmailov, Mikhail Solodov)

Global convergence of augmented Lagrangian methods applied to

optimization problems with degenerate constraints, including problems with complementarity constraints

We consider global convergence properties of the augmented Lagrangian methods on problems with degenerate constraints, with a special emphasis on mathematical programs with complementarity constraints (MPCC). In the general case, we show convergence to stationary points of the problem under an error bound condition for the feasible set (which is weaker than constraint qualifications), assuming that the iterates have some modest features of approximate local minimizers of the augmented Lagrangian. For MPCC, we obtain a rather complete picture, showing that under the usual in this context MPCC-linear independence constraint qualification accumulation points of the iterates are C-stationary for MPCC (better than weakly stationary), but in general need not be M-stationary (hence, neither strongly stationary). Numerical results demonstrate that in terms of robustness and quality of the outcome augmented Lagrangian methods are absolutely competitive with the best existing alternatives and hence, they can serve as a promising global strategy for problems with degenerate constraints.

Walter Morris, George Mason University

Efficient computation of a canonical form for a generalized P-matrix

We use recent results on algorithms for Markov decision problems to show that a canonical form for a generalized P-matrix can be computed, in some important cases, by a strongly polynomial algorithm.

Conic programming

Thu.3.H 2036

Conic optimization and signal processing applications

Organizer/Chair Anthony Man-Cho So, The Chinese University of Hong Kong · Invited Session

Senshan Ji, The Chinese University of Hong Kong (with Anthony Man-Cho So)

Approximating a KKT point of Schatten p -quasi-norm minimization in polynomial time, with applications to sensor network localization

In this talk, we consider the Schatten p -quasi norm minimization problem, which has previously found applications in compressed sensing and matrix completion. We propose a potential reduction algorithm to approximate a KKT point of the Schatten p -quasi norm minimization problem. We show that our algorithm is a fully polynomial-time approximation scheme, taking no more than $O(\frac{n}{\epsilon} \log \frac{1}{\epsilon})$ iterations to reach an ϵ -KKT point or global minimizer. We then apply the algorithm to the sensor network localization problem. Our numerical results show that in many cases, the proposed algorithm can achieve better results than the standard semidefinite relaxation of the problem.

Wing-Kin Ma, The Chinese University of Hong Kong

Semidefinite relaxation in wireless communications: Forefront developments, advances and challenges

Semidefinite relaxation (SDR) is well-known to be an efficient high-performance technique for approximating a host of hard, nonconvex optimization problems. And one of its most recognized applications is probably MAXCUT. In fact, SDR has also made its way to signal processing and wireless communications, and the impact is tremendous – today we see not only numerous applications, but also new fundamental concepts and theory driven by the applications themselves. This talk will focus on transmit beamforming, now a key topic in communications. I will provide an overview on its scope, which is quite broad (classical multiuser downlinks, unicasting and multicasting, multicell coordinated multiuser downlinks, cognitive radio, physical layer security, relaying, ...). I will then describe some latest advances that link up fundamentally meaningful optimization studies, like chance-constrained optimization, and rank-two SDR. This will be followed by an open discussion on some mysteries and challenges, noticed by researchers in simulations. For example, why does SDR give us a rank-one solution for some hard problems that involve semi-infinite quadratic constraints, seemingly all the time?

Yang Yang, The Hong Kong University of Science and Technology (with Daniel Palomar, Francisco Rubio, Gesualdo Scutari)

Multi-portfolio optimization: A variational inequality approach

In this paper, we study the multi-portfolio optimization problem with square-root market impact model using a game-theoretic approach. Contrary to the linear market impact model, available tools such as potential game theory are not applicable for the square-root model. We approach this problem using Variational Inequality, and give a comprehensive and rigorous analysis on the properties of the Nash Equilibrium such as existence and uniqueness, and devise efficient algorithms with satisfactory convergence property. A more general game problem where all accounts are subject to global constraints is also studied under the framework of Variational Inequality.

Conic programming

Thu.3.H 2038

Recent developments of theory and applications in conic optimization I

Organizers/Chairs Hayato Waki, Kyushu University; Masakazu Muramatsu, The University of Electro-Communications · Invited Session

Muddappa Gowda, University of Maryland, Baltimore County

On the nonhomogeneity and the bilinearity rank of a completely positive cone

Given a closed cone C in R^n , the completely positive cone of C is the convex cone K generated by matrices of the form uu^T as u varies over C . Examples of completely positive cones include the positive semidefinite cone (when $C = R^n$) and the cone of completely positive matrices (when $C = R_+^n$). Completely positive cones arise, for example, in the reformulation of a nonconvex quadratic minimization problem over an arbitrary set with linear and binary constraints as a conic linear program. This talk deals with the questions of when (or whether) K is self-dual, irreducible, and/or homogeneous. We also describe the bilinearity rank of K in terms of that of C .

Masakazu Muramatsu, The University of Electro-Communications (with Levent Tunçel, Hayato Waki)

A perturbed sums of squares theorem for polynomial optimization and its applications

We prove a property of positive polynomials on a compact set with a small perturbation. When applied to a POP, the property implies that the optimal value of the corresponding SDP relaxation with sufficiently large order is bounded below by $f^* - \epsilon$ and from above by $f^* + \epsilon(n+1)$, where f^* is the optimal value of the POP, n is the number of variables, and ϵ is the perturbation. In addition to extending this property to some directions, we propose a new sparse SDP relaxation based on it. In this relaxation, we positively exploit the numerical errors naturally introduced by numerical computation. An advantage of our SDP relaxation is that they are of considerably smaller dimensional than Lasserre's, and in many situation than the sparse SDP relaxation proposed by Waki et al. We present some applications and the results of our computational experiments.

Farid Alizadeh, Rutgers University

Some geometric applications of abstract algebraic sum-of-squares cones

We have established that sum-of-squares (SOS) cones in abstract algebras are semidefinite representable. By combining this fact and the classical theorem of Youla, it can be shown that a wide variety of cones are in fact SOS with respect to some algebra, and thus SD-representable. We review some applications of such cones in geometric optimization. We examine the minimum volume ellipsoid, the minimum volume rectangular box, the minimum volume simplex, etc., containing a space curve. We also examine the diameter of a space curve, distance of a point to a space curve, and possible optimization problems with constraints on such parameters. For instance we examine design of a space curve with constraints on its curvature. We will also comment on similar problem for higher dimensional surfaces.

Derivative-free & simulation-based opt.

Thu.3.H 3003A

Recent progress in direct search methods

Organizers/Chairs Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory · Invited Session

Sébastien Le Digabel, Polytechnique Montréal (with Charles Audet, Andrea Ianni, Christophe Tribes)

The mesh adaptive direct search algorithm with reduced number of directions

The Mesh Adaptive Direct Search (MADS) class of algorithms is designed for blackbox optimization where the objective function and constraints are typically computed by launching a time-consuming computer simulation. The core of each iteration of the algorithm consists of launching the simulation at a finite number of trial points. These candidates are constructed from MADS directions. The current and efficient implementation of MADS uses $2n$ directions at each iteration, where n is the number of variables. The scope of the present work is the reduction of that number to a minimal positive spanning set of $n+1$ directions. This transformation is generic and can be applied to any method that generates more than $n+1$ MADS directions.

José Mario Martínez, University of Campinas (with Luis Felipe Bueno, Ana Friedlander, Francisco Sobral)

Inexact restoration method for derivative-free optimization with smooth constraints

A new method is introduced for solving constrained optimization problems in which the derivatives of the constraints are available but the derivatives of the objective function are not. The method is based

on the Inexact Restoration framework, by means of which each iteration is divided in two phases. In the first phase one considers only the constraints, in order to improve feasibility. In the second phase one minimizes a suitable objective function subject to a linear approximation of the constraints. The second phase must be solved using derivative-free methods. An algorithm introduced recently by Kolda, Lewis, and Torczon for linearly constrained derivative-free optimization is employed for this purpose. Under usual assumptions, convergence to stationary points is proved. A computer implementation is described and numerical experiments are presented.

Rohollah Garmanjani, University of Coimbra (with Luis Nunes Vicente)

Smoothing and worst case complexity for direct-search methods in non-smooth optimization

For smooth objective functions it has been shown that the worst case cost of direct-search methods is of the same order as the one of steepest descent. Motivated by the lack of such a result in the non-smooth case, we propose, analyze, and test a class of smoothing direct-search methods for the optimization of non-smooth functions. Given a parameterized family of smoothing functions for the non-smooth objective function, this class of methods consists of applying a direct search for a fixed value of the smoothing parameter until the step size is relatively small, after which the smoothing parameter is reduced and the process is repeated. One can show that the worst case complexity (or cost) of this procedure is roughly one order of magnitude worse than the one for direct search or steepest descent on smooth functions. The class of smoothing direct-search methods is also showed to enjoy asymptotic global convergence properties. Numerical experience indicates that this approach leads to better values of the objective function, apparently without an additional cost in the number of function evaluations.

Finance & economics

Thu.3.H 3021

Modern portfolio optimization

Chair Eligius Hendrix, Málaga University

Süleyman Özekici, Koç University (with Turan Bulmuş)

Portfolio selection with hyperexponential utility functions

We analyze a single-period portfolio selection problem where the investor maximizes the expected utility of the terminal wealth. The utility function is hyperexponential. This is due to the fact that the risk tolerance of the investor at the end of the period when the terminal wealth is realized depends on the random state of the market at that time. This setting is also applicable in cases where an investment consultant is not sure about the risk profile of a client. It is well-known that an investor is memoryless in wealth for exponential utility functions with some known risk tolerance. In other words, the investment portfolio consisting of risky stocks does not depend on the level of wealth. However, we show that this is no longer true if the utility function is hyperexponential. We also obtain a number of interesting characterizations on the structure of the optimal policy.

Eligius Hendrix, Málaga University (with Leocadio Casado, Juan Francisco Herrera, Michiel Janssen)

On finding optimal portfolios with risky assets

Since the introductory work of Markowitz, the questions of finding optimal portfolios in order to maximise return and minimise risk, have been made explicit in terms of optimisation models. As long as returns are described by normal distributions, analytical expressions can be derived for finding optimal portfolio weights. The optimal mix is more difficult to find when we are dealing with so-called fat tails. This means that probabilities on extreme outcomes are typically higher than in the normal distribution, thus providing a challenge for the composition of low risk portfolios. A general way to do so is to combine simulation of rare events with optimization tools. In this context, a specific weight adjusting algorithm is described and compared to the use of standard nonlinear optimization solving an equivalent problem.

Finance & economics

Thu.3.H 3027

Applications in finance

Chair Janos Mayer, University of Zurich

Jonas Ekblom, Linköping University (with Jörgen Blomvall)

Optimal hedging of foreign exchange risk in uncertain cash flows using stochastic programming

We build a stochastic programming framework for optimal hedging of foreign exchange risk in uncertain cash flows. By incorporating term premia we are able to estimate the cost of hedging, and we determine

the optimal hedge by minimizing a convex combination of risk (measured as CVaR) and cost. The importance of expected returns for the optimal hedge is verified through numerical results. In this framework, trades are made at market prices and transaction costs are included. The framework offers great flexibility regarding distributional assumptions of the underlying risk factors and the types of financial instruments which can be included.

Mathias Barkhagen, Linköping University (with Jörgen Blomvall)

An optimization based method for arbitrage-free estimation of the implied risk neutral density surface

Accurate pricing of OTC derivatives which is consistent with noisy market prices presents a major challenge. The pricing accuracy will crucially depend on using arbitrage-free inputs to the pricing engine. To this end we develop a general optimization based framework for estimation of the option implied risk neutral density (RND) surface, while satisfying no-arbitrage constraints. The developed framework is a generalization of existing models such as the Heston model. Thus, the method considers all types of realistic surfaces and is hence not constrained to a certain function class. Instead the RND is discretized making it possible to use standard solvers for the problem. The approach leads to an optimization model where it is possible to formulate the constraints as linear constraints. The linear constraints and the form of the objective function leads to an inherent problem structure which may be utilized to speed up calculations. We show that our method produce smooth local volatility surfaces that can be used for pricing and hedging of OTC derivatives. Statistical tests demonstrate that our method gives better results than the Heston model in terms of yielding stable RNDs.

Janos Mayer, University of Zurich (with Thorsten Hens)

Portfolio optimization with objective functions from cumulative prospect theory

We consider portfolio optimization problems with several assets, involving objective functions from the cumulative prospect theory (CPT) of Tversky and Kahneman (1992). These are numerically difficult optimization problems since the objective function to be maximized is neither concave nor smooth. We have implemented an adaptive simplex grid method for the solution of this type of problems and report on the results of a numerical study. Levy and Levy (2004) proved that under the assumption of normally distributed returns the CPT efficient set is a subset of the mean-variance (MV) frontier. In fact the authors state that there is no need for separate solution algorithms for CPT-optimization, since those problems are readily solvable by maximizing the CPT objective function along the MV frontier. We compare this suggestion with the direct CPT-optimization, for a real life data-set and for several investors and find that the two approaches lead to substantially different portfolios. This difference increases dramatically if we add a call option to our data-set and it diminishes almost completely for a data-set obtained by sampling from the corresponding normal distribution.

Game theory

Thu.3.MA 005

New models and solution concepts I

Chair Daniel Granot, Sauder School of Business

Leqin Wu, Institute of Computational Mathematics and Scientific/Engineering Computing (with Xin Chen, Ye Lu, Ya-xiang Yuan)

A new solution concept for cooperative games

In this talk, we give a new solution concept for utility-transferable cooperative games. Instead of defining a representative function, we first study the sub-coalition structure and give the concept of stability, then we analyze allocation in the grand coalition based on the stable sub-coalition structure, and give a new solution concept. Moreover, we combine our theoretical result with a specific price-payoff model and find some interesting observations.

Daniel Granot, Sauder School of Business (with Eran Hananay)

Subgame perfect consistent stability

We introduce an approach to farsightedness that provides a non-cooperative foundation for this concept based on vNM type stability and subgame perfect equilibrium. We refer to the set of outcomes derived by this approach as subgame perfect consistent set (SPCS), and demonstrate that it significantly improves upon Chwe's farsighted reasoning as embodied in his largest consistent set. We further show that the SPCS approach leads, quite remarkably, to Pareto efficiency in various settings including Bertrand and Cournot competitions.

Game theory

Thu.3.MA 043

Software piracy and mastermind

Chair Carola Winzen, Max-Planck-Institut für Informatik

Yael Perlman, Department of Management, Bar-Ilan University (with Konstantin Kogan, Yaacov Ozinci)

Software piracy prevention and price determination

We consider a monopolistic producer offering software that is updated periodically, but, by the end of one period, a pirated version is available at a transaction cost. This presents the heterogeneous consumer with possible strategies for either buying a new product or pirating it. We address pricing and protection investment strategies to regain the profits affected by the piracy. In particular, we find that even when the transaction cost is exogenous, the producer does not necessarily want to fully price out the piracy. The decisive factor in such a case is the level of product newness relative to the transaction cost. If the producer is able to achieve high newness for the updated product relative to the transaction cost, then a high retail price ensures that he will gain the largest profit possible even though some of the demand will be lost due to piracy. On the other hand, when the transaction cost is endogenous, the producer may have two alternatives: pricing the software out or investing heavily in software protection. As newness levels rise, the option of pricing out the piracy becomes increasingly preferable.

Carola Winzen, Max-Planck-Institut für Informatik (with Benjamin Doerr, Reto Spöhel, Henning Thomas)

Playing mastermind with many colors

We consider the black-peg version of Mastermind with n holes and $k \leq n$ colors. For the most interesting case $k = n$, by combining previous approaches of Chvátal [Combinatorica 3 (1983), 325–329] and Goodrich [Information Processing Letters 109 (2009), 675–678], we show that there exists a deterministic winning strategy that allows the code-breaker to find the secret code with $O(n \log^{1/2} n)$ guesses. This improves the previously best known bounds of Chvátal, Goodrich, and others, which are all of order $n \log n$; both for the black-peg version of Mastermind and the original game with both black and white answer-pegs. More generally, one of the key arguments, the success probability of random sampling, can be applied to the Mastermind game with any number $k \leq ne^{-\log^{1/2} n}$ of colors, and it yields a winning strategy using $O(n \log k / \log(n/k))$ guesses.

Global optimization

Thu.3.H 2053

Advances in global optimization III

Chair Duy Van Nguyen, Universität Trier

Tibor Csendes, University of Szeged (with Elvira Antal)

Symbolic simplification of nonlinear optimization problems

We present a Maple implementation of a symbolic algorithm that is capable to transform the original nonlinear global optimization problem into an equivalent form, that is simpler in the sense that it has less operations to be calculated. The algorithm can also recognize redundancy in the optimized variables, and in this sense it can decrease the dimensionality of the problem (if it is possible). The applied transformations can preserve the number of local minimizer points, and the solution of the transformed problem can easily be transformed back to the space of the original variables.

We have tested the code on the set of standard global optimization problems and on some custom made simplifiable problems. The results are convincing in terms that the algorithm concluded in almost all cases according to our knowledge on the problems.

Csendes, T. and T. Rapcsák: Nonlinear Coordinate Transformations for Unconstrained Optimization. I. Basic Transformations, J. of Global Optimization 3(1993) 213–221.

Chu Nguyen, Eastern Asian University of Technology (with Nguyen Chu, Pham Duong, Le Hue)

The interior exterior approach for linear programming problem

In this paper we present a new interior exterior algorithm for solving linear programming problem which can be viewed as a variation of simplex method in combination with interior approach. With the assumption that a feasible interior solution to the input system is known, this algorithm uses it and appropriate constraints of the system to construct a sequence of the so called station cones whose vertices tend very fast to the solution to be found. The computational experiments show that the number of iterations of the interior exterior algorithm is significantly smaller than that of the second phase of the simplex method. Additionally, when the number of variables and constraints of the problem

increase, the number of iterations of the interior exterior approach increase in a slower manner than that of the simplex method.

Duy Van Nguyen, Universität Trier

Solving standard problem (StQP)

We consider the standard quadratic problem (StQP) which consists of globally minimizing an indefinite quadratic function over the simplex. We propose a finite but exponential solution algorithm in which the main task of each iteration is to check semidefiniteness of a $k \times k$ symmetric matrix with $k \leq n$. We show some illustrative examples and computational test results for the algorithm.

Implementations & software

Thu.3.H 1058

Modeling languages and software III

Chair Robert Fourer, AMPL Optimization

Per Rutquist, Tomlab Optimization (with Marcus Edvall, Kenneth Holmström)

Trajectory optimization with TOMLAB/PROPT

We demonstrate an easy-to-use symbolic interface for trajectory optimization, and for general linear and nonlinear programming, using Matlab syntax.

PROPT allows ordinary differential equations (as well as more general differential algebraic equations) to be converted into optimization constraints using pseudo-spectral collocation. Multi-phase problems and links to time-independent equations are also handled in a straightforward manner.

Equations are entered via the symbolic interface TOMSYM, which automatically generates the linear constraint matrix as well as derivatives of nonlinear functions. These are then integrated with the entire TOMLAB suite of solvers, which includes mixed-integer optimization with KNITRO and MINLPBB and global optimization with multiMin. As a result, we achieve very good results on many problems described as “hard” in literature. As illustration, we present solved examples from robotics, aerospace, process control and parameter estimation.

Christian Valente, OptiRisk Systems (with Gautam Mitra, Victor Zverovich)

Optimisation under uncertainty: Software tools for modelling and solver support

Algebraic modelling languages are now well established as a formulation tool used by practitioners and academics in the field of operational research. We describe an integrated modelling and solver platform for investigating stochastic and robust optimisation models. We consider the following well known approaches: stochastic programming (SP) with recourse, chance constrained programming, integrated chance constrained programming, and robust optimisation.

In an earlier work Valente et al. introduced Stochastic extensions of AMPL called SAMPL. The extended language constructs are used to represent two- and multi-stage SP problems. In this paper we describe a set of extensions to SAMPL for representing robust optimisation problems and the additional classes of SP problems listed above. We not only describe syntax and semantics of the extensions but also discuss solver requirements, reformulation techniques and connection between the modelling system and external solvers. In particular, we show that direct representation of some of the modelling constructs not only makes the models easier to understand but also facilitates the use of specialised solution algorithms.

Vincent Beraudier, IBM Industry Solution (with Ferenc Katai, Arnaud Schulz)

Modeling best practices: How to write good optimization models efficiently thanks to IBM ILOG CPLEX Optimization Studio's Integrated Development Environment (IDE) and its debugging support

A good optimization model has to execute fast, but also it has to be scalable to adapt to changes in data and/or constraints. Therefore at development time, debugging support is a crucial factor to deliver scalable optimization models into solutions. This interactive demo will show the debugging capabilities to deal with optimization model testing in IBM ILOG CPLEX Optimization Studio. The talk will consist in a showcase on an application developed by IBM. It will describe in fair amount of details how OPL language and its IDE helps its users to detect memory and time bottlenecks in an optimization model. It will show how OPL provides its users introspection mechanisms to detect issues early on, to avoid them, and eventually to eliminate errors as soon as possible in the development process. We will also discuss how the OPL language and Studio ensure quality throughout the entire application life-cycle, from design to deployment.

Integer & mixed-integer programming**Thu.3.H 2013****Topology, clustering and separation**

Chair Timo Berthold, ZIB / Matheon

Marcia Fampa, Universidade Federal do Rio de Janeiro (with Olinto Araújo, Viviane Kohler)

MILP formulation for the software clustering problem

We present a mixed integer linear programming (MILP) formulation for the Software Clustering Problem (SCP), where we divide the modules of a software system into groups or clusters, to facilitate the work of the software maintainers. We discuss a preprocessing that reduces the size of the instances of the SCP and introduce some valid inequalities that have been shown to be very effective in tightening the MILP formulation. Numerical results presented compare the results obtained with the formulation proposed with the solutions obtained by the exhaustive algorithm supported by the freely available Bunch clustering tool, for benchmark problems.

Pedro Guillén, Universidad Politécnica de Madrid (UPM), Natural Computing Group (with Juan Castellanos, Alejandro De Santos, Eduardo Villa)

Natural languages with the morphosyntactic distance as a topological space

The main aim of this paper is to give a proof of the computability of morphosyntactic distance (M.D.) over an arbitrary set of data. Since here, M.D. (defined in the works of De Santos, Villa and Guillén) can be defined over the elements of this group. Distance d induces a topological space, that we call morphosyntactic space. Based on these hypothesis, studying the properties of this space from a topological point of view. Let the associated lexical space built, that has a semigroup structure, and could be treated as a set, regardless of its algebraic properties. Using the fact that the meaning function is injective, it is possible to define on it the M.D. d .

In the first section, several topological properties of morphosyntactic space are proved: total disconnection, compactness and separability. Then a comparison is proposed between different structures and morphosyntactic space.

Under the latter theorem, reasonable time to implement algorithms can be assumed over morphosyntactic space. In these conditions, is easy to conclude that the model designed to define the morphosyntactic space is computable, and therefore the algorithm of M.D. is solvable.

Inácio Andruski-Guimarães, UTFPR – Universidade Tecnológica Federal do Paraná

Comparison of techniques based on linear programming to detect separation

Separation is a key feature in logistic regression. In fact, is well known that, in case of complete separation, iterative methods commonly used to maximize the likelihood, like for example Newton's method, do not converge to finite values. This phenomenon is also known as monotone likelihood, or infinite parameters. Linear programming techniques to detect separation have been proposed in the literature for logistic regression with binary response variable. But, for polytomous response variable, the time required to perform these techniques can be greater than that for fitting the model using an iterative method. The purpose with this job is to develop and implement an alternative approach to detect separation for the parameter estimation in polytomous logistic regression. This approach proposes to use as covariates a reduced set of optimum principal components of the original covariates. Principal components analysis allows the reduction of the number of dimensions and avoiding the multicollinearity of these variables. Examples on datasets taken from the literature show that the approach is feasible and works better than other techniques, in terms of amount of computing.

Integer & mixed-integer programming**Thu.3.H 2032****Branch-and-price IV: Primal heuristics**

Organizer/Chair Marco Lübbecke, RWTH Aachen University · Invited Session

Christian Puchert, RWTH Aachen University (with Marco Lübbecke)

Large neighborhood search and diving heuristics in column generation algorithms

In many MIP applications, a problem with a particular structure is to be solved. For those problems, the branch-and-price scheme using the column generation procedure has proven to be a successful approach, which relies on the Dantzig-Wolfe decomposition.

The performance of this scheme may be improved by supplying it with additional features such as primal heuristics. We present heuristics that are specially tailored for Column Generation and exploit a given problem structure, but are still generic in that they are not restricted to any particular problem.

In particular, we lay focus on two special kinds of heuristics, namely large neighborhood search and diving heuristics. The former explore a MIP neighborhood of one or more given feasible (or at least LP feasible) solutions. The latter perform a depth-first search on the branch-and-bound tree, where they may branch either on the original variables or the master variables. We will investigate the impact of these heuristics and give a comparison to classical heuristic approaches.

François Vanderbeck, University of Bordeaux & INRIA (with Cédric Joncour, Sophie Michel, Pierre Pesneau, Artur Pessoa, Marcus Poggi, Ruslan Sadykov, Eduardo Uchoa)

Primal heuristics for branch-and-price

Primal heuristics have become an essential component in mixed integer programming (MIP). Generic heuristic paradigms of the literature remain to be extended to the context of a column generation solution approach. As the Dantzig-Wolfe reformulation is typically tighter than the original compact formulation, techniques based on rounding its linear programming solution have better chance to yield good primal solutions. However, the dynamic generation of variables requires specific adaptation of heuristic paradigms. We develop diving methods and consider their combination with sub-MIPing, relaxation induced neighborhood search, truncated backtracking using a Limited Discrepancy Search, and feasibility pump. These add-ons serve as local-search or diversification/intensification mechanisms.

Michael Bastubbe, RWTH Aachen, Chair of Operations Research (with Martin Bergner, Alberto Ceselli, Marco Lübbecke)

A branch-and-price algorithm for rearranging a matrix into doubly bordered block-diagonal form

We consider rearranging the rows and the columns of a matrix into doubly bordered block-diagonal (a.k.a. arrowhead) form. For a given number of blocks and some given balance condition on the blocks, this becomes an optimization problem in which the total number of border rows and border columns is to be minimized. In this talk we present an exact branch-and-price algorithm to this optimization problem.

For us, this matrix form is particularly interesting because it may help us applying a Dantzig-Wolfe decomposition of the underlying mixed integer program.

We extend a naive assignment IP formulation (that has a weak LP relaxation) by an exponentially number of block pattern variables to strengthen the LP relaxation. Our branch-and-price algorithm first solves the pricing problem heuristically by exploiting its special structure. If the heuristic solution of the pricing problem does not yield variables with negative reduced costs the pricing problem is solved exactly by an IP. We present the improvement of the LP relaxation and discuss the practicability of the algorithm.

Integer & mixed-integer programming**Thu.3.H 2033****Mixed-integer linear and semidefinite programs**

Organizer/Chair Marc Pfetsch, TU Darmstadt · Invited Session

Sonja Mars, TU Darmstadt (with Jakob Schelbert, Lars Schewe)

Approaches to solve mixed integer semidefinite programs

We present a hybrid approach for solving mixed integer SDPs, which alternates between solving SDP- and LP-relaxations. We implemented this approach in SCIP and provide an interface to SDP-solvers. Therefore we added new features concerning presolving, heuristics and separation. Additionally to solving the SDPs directly, we approximate the SDP cone using linear inequalities and solve LP-relaxations. Our framework can be used as a pure branch-and-cut-algorithm with solving SDP-relaxations. Furthermore it is possible to just use the linear approximations for solving. Our main focus lies on the comparison of the interaction of the two relaxations. For this we present numerical results. Our studies are motivated by one main application. We consider problems from mechanical engineering in the context of truss topology design. The standard formulation of a truss problem is extended to discrete bar areas and actuators. These components are modeled via binary variables. Additionally we show results for other classes of MISDPs.

Nam Dung Hoang, Vietnam National University Hanoi (with Thorsten Koch)

Steiner tree packing revisited

The Steiner tree packing problem (STPP) in graphs is a long studied problem in combinatorial optimization. In contrast to many other problems, where there have been tremendous advances in practical problem solving, STPP remains very difficult. Most heuristics schemes are ineffective and even finding feasible solutions is already NP-hard. What makes this problem special is that in order to reach the overall optimal solution non-optimal solutions to the underlying NP-hard Steiner tree problems must be used. Any non-global approach to the STPP is likely to fail. Integer programming is currently the best approach for computing optimal solutions. In this talk we review some classical STPP

instances which model the underlying real world application only in a reduced form. Through improved modelling, including some new cutting planes, and by employing recent advances in solver technology we are for the first time able to solve those instances in the original 3D grid graphs to optimality.

Matthias Miltenberger, Zuse Institute Berlin

Advances in linear programming

The efficient and reliable solution of today's optimization problems remains an interesting and challenging task, especially when dealing with large-scale instances. A lot of these are formulated as mixed integer programs that rely on branch-and-cut to compute an optimal solution. In this process usually many linear relaxations (LPs) have to be solved and the simplex method has proven successful in this task. We shed light on the impact of LP solving within the MIP context and present recent progress in the area, in particular with respect to the academic solvers SCIP and SoPlex.

Life sciences & healthcare

Thu.3.MA 376

Mathematical modeling of disease

Chair Rujira Ouncharoen, Chiang Mai University

Ivan Savic, Faculty of Technology, University of Nis (with Ljubisa Nikolic, Vesna Nikolic, Ivana Savic, Mihajlo Stankovic)

Mathematical modeling of amygdalin isolation from plum kernel using response surface methodology

Amygdalin belongs in the group of anticancer agents. It has a high application in treatment of cancer, because of its selective impact on the tumor cells. The aim of this study was to model and optimize a process of amygdalin isolation from plum kernel (*Nucleus Prunus Domestica*) using response surface methodology. The time of extraction, ethanol concentration, the ratio of plant material to solvent and temperature were used as independent variables, while the yield of amygdalin as dependent variable for central composite design. The second order polynomial model was successfully applied for mathematical modeling of this process. A correlation coefficient of 0.7768 indicates on a good fitting of observed with predicted data. By desirability function, the extraction process was optimized. The optimal amygdalin yield of 15.83 g/100 g d.e. was achieved after 120 min using 20 % ethanol at the solvmodule of 1 : 25 (m/V) and temperature of 78° C.

Rujira Ouncharoen, Chiang Mai University (with Thongchai Dumrongpochaphan, Siriwan Intawichai)

Stability of HIV aphaeresis model

The new approach in treating the human immunodeficiency virus (HIV) infection is aphaeresis. It is a method of collecting larger quantities of certain blood components that can safely be collected through a simple blood draw. In this paper, we investigate the effect of HIV aphaeresis in a model of HIV infection. Sufficient conditions are given to ensure the endemic equilibrium point is stable which mean the viral load is under control.

Logistics, traffic, and transportation

Thu.3.H 0106

Logistics and transportation

Organizer/Chair Arash Asadpour, New York University - Stern School of Business - Invited Session

Arash Asadpour, New York University - Stern School of Business (with Michel Goemans, Aleksander Madry, Shayan Oveis Gharan, Amin Saberi)

Rounding by sampling and an $O(\log n / \log \log n)$ approximation algorithm for ATSP

We study the relation between the integer linear programming models for a class of discrete optimization problems and their relaxations. I will introduce a new probabilistic technique for transforming the optimal solutions of these relaxed programs into the near-optimal solutions for the original discrete problems. The technique is based on sampling from maximum entropy distributions over combinatorial structures hidden in such problems.

In order to present the idea, I will go through a generalization of the Traveling Salesman Problem (Asymmetric TSP) and show how we can improve the worst-case performance guarantee for this problem after almost 30 years. We will also see other applications of this technique in assignment problems and fair resource allocation.

Nitish Korula, Google Research (with Mohammadhossein Bateni, Chandra Chekuri, Alina Ene, Mohammadtaghi Hajiaghayi, Daniel Marx)

Prize-collecting Steiner network problems on planar graphs

In this paper, we reduce Prize-Collecting Steiner TSP (PCTSP), Prize-Collecting Stroll (PCS), Prize-Collecting Steiner Tree (PCST),

Prize-Collecting Steiner Forest (PCSF), and more generally Submodular Prize-Collecting Steiner Forest (SPCSF), on planar graphs (and on bounded-genus graphs) to the corresponding problems on graphs of bounded treewidth. More precisely, for each of the mentioned problems, an α -approximation algorithm for the problem on graphs of bounded treewidth implies an $(\alpha + \epsilon)$ -approximation algorithm for the problem on planar (and bounded-genus) graphs, for any constant $\epsilon > 0$. PCS, PCTSP, and PCST can be solved exactly on graphs of bounded treewidth and hence we obtain a PTAS for these problems on planar and bounded-genus graphs. In contrast, we show that PCSF is APX-hard on series-parallel graphs, which are planar graphs of treewidth at most 2. Besides ruling out a PTAS for PCSF on planar graphs and bounded-treewidth graphs, this result is also interesting since it gives the first provable hardness separation between the approximability of a problem and its prize-collecting version. (We show similar hardness for Euclidean PCSF.)

Mohammadhossein Bateni, Google Inc. (with Mohammadtaghi Hajiaghayi, Philip Klein, Claire Mathieu)

PTAS for planar multiway cut

Given an undirected graph with edge lengths and a subset of nodes (called the terminals), a multiway cut (also called a multi-terminal cut) problem asks for a subset of edges with minimum total length and whose removal disconnects each terminal from the others. It generalizes the min st-cut problem but is NP-hard for planar graphs and APX-hard for general graphs. We give a polynomial-time approximation scheme for this problem on planar graphs. We prove the result by building a novel spanner for multiway cut on planar graphs which is of independent interest.

Logistics, traffic, and transportation

Thu.3.MA 042

Real-world applications

Chair Kaj Holmberg, Linköping University

Kaj Holmberg, Linköping University

Planning and routing in networks: Urban snow removal

We study the problem of planning service tasks in street networks, and use snow removal as a generic problem. Snow removal is (sometimes) an important problem. Drastic weather changes might become more frequent in the future, which indicates a need to handle unusual situations. Computerized optimization based tools for planning will be a help.

The goal is to find good a plan: When should each task be done, which vehicle should do the task and how should the vehicle travel between tasks. Different vehicles have different capabilities and tasks may have precedence requirements. The objective function may include finishing times, costs and environmental aspects.

The problem is too difficult to be solved by standard methods, but there are several usable structures in the problem, such as the Chinese postman problem, the rural postman problem, the asymmetric traveling salesman problem as well as scheduling with precedence constraints. We discuss solution methods containing several different heuristic parts building up and improving the solutions, using decomposition frameworks. Some preliminary conclusions from a real life example are mentioned.

Rodrigo Branchini, Universidade Estadual de Campinas – UNICAMP (with Vinicius Armentano)

Fleet deployment optimization model for tramp and liner shipping

We present a generic mixed integer mathematical programming model to tackle operational and tactical planning problems faced by liner and tramp shipping companies in maritime logistics. The liner shipping company pickups and delivers client cargoes, e.g., containers, along a pre-established route analogous to the hop-in and hop-off of passengers in a bus line. A tramp shipping company does not have a predefined route to follow, the route is constructed and executed as new demands arrive. Although the relevance of the types of decisions for each operation is different, for example daily routing decisions are more important to tramp than to liner companies, both operations share similar structure, such as the goal of profit maximization while fulfilling established contracts agreements, and may have part of the decision making process modeled and solved using a generic MIP formulation. The decisions addressed by the model are the definition of fleet size and mix (e.g., which vessels to charter in/out or lay-up), the evaluation of spot voyages contracts and the determination of vessel routes and schedules. The model was implemented with CPLEX and computational results are reported.

Mixed-integer nonlinear programming

Thu.3.MA 001

Mixed-integer nonlinear programming

Organizer/Chair Jon Lee, University of Michigan · Invited Session

Shmuel Onn, Technion – Israel Institute of Technology

Integer programming in polynomial time via Graver bases

I will overview our algorithmic theory which uses Graver bases to solve linear and nonlinear integer programming problems in variable dimension in polynomial time. I will demonstrate the power of this theory by describing some of its many applications including to multiway statistical table problems, multicommodity flows and stochastic integer programming, and will show that this theory is universal and provides a new parametrization of all of integer programming. I will also mention a very recent drastic improvement from polynomial to cubic running time. The talk draws from my recent monograph on nonlinear discrete optimization and is based on several papers joint with several colleagues including Berstein, De Loera, Hemmecke, Lee, Romanchuk, Rothblum and Weismantel.

Renata Sotirov, Tilburg University

SDP relaxations for the graph partition problem

In [R. Sotirov. A powerful semidefinite programming relaxation for the graph partition problem. Manuscript 2011] we derived a semidefinite programming relaxation for the general graph partition problem (GPP) that is based on matrix lifting. This relaxation provides competitive bounds that can be computed with little computational effort for graphs with up till 100 vertices.

Here, we further investigate matrix and vector lifting SDP relaxations for the GPP on highly symmetric graphs, and improve the best known bounds for certain graphs with symmetry.

Raymond Hemmecke, TU Munich (with Shmuel Onn, Lyubov Romanchuk)

N-fold integer programming in cubic time

In this talk we present a cubic-time algorithm for solving N-fold integer programs together with some first computational experiments on its performance.

Multi-objective optimization

Thu.3.H 1029

Preference structures in multi-objective optimization

Organizer/Chair Gabriele Eichfelder, TU Ilmenau · Invited Session

Gabriele Eichfelder, TU Ilmenau

A procedure for solving vector optimization problems with a variable ordering structure

Vector optimization problems with a variable ordering structure have recently gained interest due to several applications for instance in image registration and portfolio optimization. Here, the elements in the image space are compared using a cone-valued map, called ordering map, which defines an ordering cone for each element of the image space individually. This leads to a binary relation, which is in general not transitive and also not compatible with the linear structure of the space. We present in this talk a numerical method for determining an approximation of the optimal solution set of such (nonlinear and smooth) vector optimization problems.

In a first step, using classical adaptive approximation methods, a superset of the set of optimal solutions is determined. In a second step, using new nonlinear scalarization results for variable ordering structures, the optimal elements are selected. First numerical results are presented.

Behnam Soleimani, Martin-Luther-Universität Halle-Wittenberg

Approximate solutions of vector optimization with variable order structure

We introduce concepts for approximate minimal and nondominated solutions of vector optimization problems with variable order structure. Furthermore, we introduce a scalarization method by means of nonlinear functionals and present a characterization of approximate minimal and nondominated solution by using this scalarization method.

Refaik Kasimbeyli, Anadolu University

Characterization of properly nondominated elements in vector optimization with variable ordering structures

This paper studies properly nondominated elements in vector optimization problems with variable ordering structures. We introduce several notions for properly nondominated elements and investigate nonlinear scalarization approach for their characterizations. A new concepts presented in the paper are compared to existing in literature ones. The new type of nonlinear scalarizing functions is introduced and their

properties are discussed. These functions are used to characterize the properly nondominated elements.

Nonlinear programming

Thu.3.H 0107

Algorithms and applications II

Organizer/Chair Ya-xiang Yuan, Chinese Academy of Sciences · Invited Session

Jinyan Fan, Shanghai Jiao Tong University

Accelerating the modified Levenberg-Marquardt method

In this talk, we will present an accelerated version of the modified LM method for nonlinear equations, which not only computes a LM step but also an approximate LM step with line search at every iteration. Under the local error bound condition which is weaker than nonsingularity, we show the convergence order of the accelerated modified LM method is a continuous function with respect to the LM parameter. We compare the new method with both the LM method and the modified LM method and observe significantly competitive performance.

Yanfei Wang, Institute of Geology and Geophysics, Chinese Academy of Sciences

Optimizing inversion methods for seismic imaging

In this talk we address several migration and optimizing inversion methods in seismic imaging. In particular, regularizing least squares migration and inversion imaging techniques are discussed. Preconditioning technique is also introduced. Numerical tests are made to show the performance of the methods. Since the interferometric migration and the least squares migration both aim to improve the resolution of seismic imaging, a numerical experiment is also made to discuss their ability in improving imaging resolution.

Torsten Bosse, Humboldt Universität zu Berlin (with Levis Eneya, Andreas Griewank)

Limited memory updating and quadratic overestimation for NLOP

We pursue the approach of solving non-linearly constraint problems using an active set strategy without the complete evaluation of Jacobians or Hessians. The linearized KKT systems are solved approximately on the basis of limited derivative information and compact storage schemes. The resulting step corresponds to a projected Hessian who's positive definiteness is ensured with the help of quadratic overestimation. We will present theoretical arguments and numerical experiments.

Nonlinear programming

Thu.3.H 0110

Polynomial optimization and semidefinite programming

Organizer/Chair Jiawang Nie, University of California, San Diego · Invited Session

Lihong Zhi, Academy of Mathematics and Systems Science (with Yue Ma)

Computing real solutions of polynomial systems via low-rank moment matrix completion

We propose a new algorithm for computing real roots of polynomial equations or a subset of real roots in a given semi-algebraic set described by additional polynomial inequalities. The algorithm is based on using modified fixed point continuation method for solving Lasserre's hierarchy of moment relaxations. We establish convergence properties for our algorithm. For a large-scale polynomial system with only few real solutions in a given area, we can extract them quickly. Moreover, for a polynomial system with an infinite number of real solutions, our algorithm can also be used to find some isolated real solutions or real solutions on the manifolds.

Cordian Riener, University of Konstanz

Symmetry in polynomial optimization

Solving polynomial optimization problems is known to be a hard task in general. In order to turn the recently emerged relaxation paradigms into efficient tools for these optimization questions it is necessary to exploit further structure whenever presented in the problem structure. In this talk we will focus on the situation of optimization problems that are given by symmetric polynomials in order to highlight several approaches to take advantage of symmetry. The techniques presented in the talk will also give a better understanding of the cones of symmetric sums of squares and symmetric non negative forms and the symmetric mean inequalities associated to these. In particular, we will show that in degree four, symmetric mean inequalities are characterized by sum of squares decomposition.

Markus Schweighofer, Universität Konstanz (with Igor Klep)

The sums of squares dual of a semidefinite program

It is now commonly known that many polynomial optimization problems can be modeled or at least approximated by semidefinite programs

Nonsmooth optimization

(SDPs). In this talk we go the other way around: We consider an SDP from the perspective of polynomial optimization and real algebraic geometry. We will see that, from this perspective, the standard duality of an SDP can be seen as a theorem on representation of positive polynomials. We will prove that natural variants of this theorem hold true, and these can be refined with some effort to yield what we call the sums of squares dual of a semidefinite program. This dual has polynomial size in the primal and, unlike the standard dual, ensures always strong duality. Based on completely different ideas, another dual with this property has already been given by Matt Ramana in 1995. However, we think that our dual is interesting because it shows that ideas from real algebraic geometry might lead very naturally to seriously exploitable concepts in optimization.

Nonlinear programming

Thu.3.H 0112

Nonlinear multilevel and domain decomposition methods in optimization

Organizer/Chair Michal Kocvara, University of Birmingham · Invited Session

Zdenek Dostal, VSB-Technical University Ostrava (with Tomas Kozubek)

Optimal massively parallel algorithms for large QP/QPQC problems arising in mechanics

We first review our results in development of optimal algorithms for the minimization of a strictly convex quadratic function subject to separable convex constraints and/or equality constraints. A unique feature of our algorithms is the bound on the rate of convergence in terms of the bounds on the spectrum of the Hessian of the cost function, independent of representation of the constraints. When applied to the class of convex QP or QPQC problems with the spectrum in a given positive interval and a sparse Hessian matrix, the algorithms enjoy optimal complexity.

The efficiency of our algorithms is demonstrated on the solution of contact problems of elasticity with or without friction by our TFETI domain decomposition method. We prove numerical scalability of our algorithms, i.e., their capability to find an approximate solution in a number of matrix-vector multiplications that is independent of the discretization parameter. Both numerical and parallel scalability of the algorithms is documented by the results of numerical experiments with the solution of contact problems with millions unknowns and analysis of industrial problems.

James Turner, University of Birmingham (with Michal Kocvara, Daniel Loghin)

Applications of domain decomposition to topology optimization

When modelling structural optimization problems, there is a perpetual need for increasingly accurate conceptual designs, with the number of degrees of freedom used in obtaining solutions continually rising. This impacts heavily on the overall computational effort required by a computer and it is therefore natural to consider alternative possibilities. One approach is to consider parallel computing and in particular domain decomposition. The first part of this talk will discuss the application of domain decomposition to a typical topology optimization problem via an interior point approach. This method has the potential to be carried out in parallel and therefore can exploit recent developments in the area. The second part of the talk will focus on a nonlinear reaction diffusion system solved using Newton's method. Current work considers applying domain decomposition to such a system using a Newton Krylov Schur (NKS) type approach. However, strong local nonlinearities can have a drastic effect on the global rate of convergence. Our aim is to instead consider a three step procedure that applies Newton's method locally on subdomains in order to address this issue.

Rolf Krause, University of Lugano

Inherently nonlinear decomposition and multilevel strategies for non-convex minimization

We present and discuss globally convergent domain decomposition and multilevel strategies for the solution of non-convex – and possibly constrained – minimization problems. Our approach is inherently nonlinear in the sense that we decompose the original nonlinear problem into many small, but also nonlinear, problems. In this way, strongly local nonlinearities or even heterogeneous problems can be handled easily and consistently. Starting from ideas from Trust-Region methods, we show how global convergence can be obtained for the case of a nonlinear domain decomposition as well as for the case of a nonlinear multilevel method – or combinations thereof. These ideas also allow us for deriving a globally convergent variant of the ASPIN method (G-ASPIN). We will illustrate our findings along examples from computational mechanics in 3D.

Thu.3.H 1012

Algorithms for nonsmooth optimization

Organizer/Chair Robert Mifflin, Washington State University · Invited Session

Robert Mifflin, Washington State University (with Claudia Sagastiz'abal)

A first step in designing a VU-algorithm for nonconvex minimization

This talk lays the ground work for designing a future VU-type minimization algorithm to run on locally Lipschitz functions for which only one Clarke generalized gradient is known at a point. This entails development of a bundle method V-algorithm that has provable convergence to stationary points for semismooth functions and can make adequate estimates of "V-subspace" bases in the presence of nonconvexity. Ordinary bundle methods generate consecutive "null steps" from a "bundle center" until a "serious step" point is found, which then becomes the next center. A VU-algorithm is similar except that its serious descent point is "very serious" which means it defines a good "V-step" and "U-gradient" pair for making an additional "U-step" to the next center. For an objective function of one variable the desired VU- algorithm exists, but it does not extend directly to functions of n variables. For convex functions about 20 years worth of proximal point and VU theory had to be developed before a rapidly convergent method for the multivariable case could be defined. For the nonconvex case two ideas from the $n = 1$ algorithm are adapted to create the desired n -variable V-algorithm.

Wellington Oliveira, IMPA

Exploring accuracy and geometry in level bundle methods

We consider level bundle methods for minimizing a nonsmooth convex function over a closed convex set. These algorithms only require evaluating the function and a subgradient with a variable accuracy. Besides handling inaccurate oracle information, if the problem is bounded, the methods can take advantage of the feasible set geometry to obtain near-optimal complexity bounds.

Adam Duorou, Orange Labs

Specialized proximal Chebychev center cutting plane algorithm for convex additive functions

The author has recently proposed an approach for convex nonsmooth optimization, which regularizes the cutting plane algorithm of Elzinga and Moore. In this talk, this approach is tailored to the case where the objective function is additive. We highlight aspects where this specialization differs from ignoring the structure of the objective function. To assess the approach, we consider some nonlinear multicommodity flows applications in telecommunications, and a comparison with a proximal bundle algorithm.

Optimization in energy systems

Thu.3.MA 549

Equilibrium models for electricity markets

Organizer/Chair Andy Philpott, University of Auckland · Invited Session

Pär Holmberg, Research Institute of Industrial Economics (IFN) (with Andrew Philpott)

Supply function equilibria in networks with transport constraints

Transport constraints limit competition and arbitrageurs' possibilities of exploiting price differences between goods in neighbouring markets, especially when storage capacity is negligible. We analyse this in markets where strategic producers compete with supply functions, as in electricity markets. A methodological problem in the past has been that transport constraints introduce kinks in producers' residual demand curves, which often lead to non-existence of Nash equilibria in oligopoly markets. We show that existence of supply function equilibria (SFE) is ensured if demand shocks are sufficiently evenly distributed, so that the residual demand curves become sufficiently smooth in expectation.

Eddie Anderson, University of Sydney Business School

When do supply function equilibria exist?

Despite the substantial literature on supply function equilibria (SFE) in electricity markets, the question of whether or not an SFE exists in pure strategies for an asymmetric problem is a difficult one. In this paper we prove the existence of a supply function equilibrium for a duopoly with asymmetric capacity constrained firms having convex non-decreasing marginal costs, with decreasing concave demand subject to an additive demand shock. The proof is constructive and also gives insight into the structure of the equilibrium solutions.

Andy Philpott, University of Auckland (with Michael Ferris, Roger Wets)

Competitive equilibrium and risk aversion in hydro-dominated electricity markets

The correspondence of competitive partial equilibrium with a social optimum is well documented in the welfare theorems of economics.

These have analogies in perfectly competitive electricity markets when agents maximize profits in a deterministic setting. When the system involves hydro reservoirs with uncertain inflows, the social optimum is the solution to a multi-stage stochastic program. This corresponds to a competitive equilibrium when all agents are risk neutral and share the same view of the future. We explore what happens in this setting when risk-averse agents optimize using coherent risk measures.

Optimization in energy systems

Thu.3.MA 550

Gas transport in networks

Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen · Invited Session

Martin Schmidt, Leibniz Universität Hannover (with Marc Steinbach)

An extended interior point method for nonsmooth nonlinear optimization in gas networks

Detailed physical and technical modeling of cost minimization in gas transport networks leads to nonsmooth nonlinear mixed-integer optimization models (NSMINLPs). After fixing prescribed discrete decisions given by an enclosing MIP framework we concentrate on the remaining nonsmooth nonlinear optimization problem (NSNLP). These problems cannot be seriously tackled by standard interior point methods due to the violation of C^2 -assumptions.

We present a modified interior point method using a special kind of generalized gradients for the search direction computation and an extended step length computation ensuring that the line-search subprocedure is only applied to smooth regions of the nonsmooth problem functions. The applicability of the proposed method is demonstrated by numerical experiments on large-scale real world instances.

Imke Joermann, TU Darmstadt

Analyzing infeasibility in natural gas networks

Infeasibilities in the mathematical description of natural gas networks in real-world applications can arise for different reasons, including defective data, modeling issues and plain physical impracticability. In the considered case, we start with a mixed integer linear program (MILP) modeling the validation of nominations on the network, i.e., the task of deciding whether it is possible to transport a given flow amount with specific supply and demand nodes.

Our main purpose is to analyze this MILP and find *physical* reasons for the infeasibility of a given instance. To achieve this, we implemented and tested various approaches based on slack models. In addition, we investigated the explanatory power of irreducible infeasible subsystems; since it is possible to calculate them at least in a heuristic way, the remaining task is to transfer the gained information from the MILP back to the network. Complementing the modeling aspects we present computational results and derive cautious suggestions as to which model should be used, depending on the practical application.

Ralf Gollmer, University of Duisburg-Essen (with Rüdiger Schultz, Claudia Stangl)

Stationary gas transport - Structure of the problem and a solution approach

Detecting feasibility of transportation orders (nominations) in gas networks is a problem of growing practical interest due to the regulatory requirements in the course of unbundling gas trading and transport. In the stationary flow case, already, this nonlinear non-convex mixed-integer problem poses challenging mathematical questions. In particular, we discuss some structural properties of the problem in slightly simplified form. We sketch a heuristic solution approach choosing switching decisions (the integer variables) from the solution of an aggregated linear transshipment problem and referring to the so called loop formulation when solving the resulting NLP. This approach is quite successful when applied to real-world instances met in a meshed gas network of a German utility.

PDE-constrained opt. & multi-level/multi-grid meth.

Thu.3.H 0111

Adjoint-based methods and algorithmic differentiation in large scale optimization

Organizer/Chair Andreas Griewank, Humboldt University · Invited Session

Nikolai Strogies, Humboldt-Universität zu Berlin (with Andreas Griewank)

A time-labeling approach for open pit mine planning

For open pit mine planning, integer or mixed integer programming approaches are well understood and investigated. In this talk a function space formulation will be presented. So called time labeling functions (TLF) assign the time of excavation to each spatial coordinate. An additional pointwise constraint replaces the predecessor relationship and

ensures the physical stability of the resulting sequence of profiles. The capacity of the mine is expressed via a density function and is allowed to vary over time. In all points this approach allows a significantly more detailed modeling of the mining operation than the usual block model. We formulate the dynamic open pit mine planning problem in a suitable function space and present a stationarity condition. Moreover we discuss properties of the TLF.

Emre Özkaya, RWTH Aachen (with Nicolas Gauger, Anil Nemili)

Automatic differentiation of an unsteady RANS solver for optimal active flow control

We present the development of a discrete adjoint solver for the optimal active flow control of viscous flows, governed by the unsteady incompressible Reynolds-averaged Navier Stokes (RANS) equations. The discrete adjoint solver is developed by applying automatic differentiation (AD) in reverse mode to the underlying primal flow solver. Employing AD for discrete adjoint code generation results in a robust adjoint solver, which gives accurate sensitivities for turbulent flows with separation. If AD is applied in a black-box fashion then the resulting adjoint code will have prohibitively expensive memory requirements. Further, a significant amount of CPU time is spent on storing and retrieving the data from the memory. In order to reduce the excessive storage and CPU costs, various techniques such as checkpointing and reverse accumulation are employed. Numerical results are presented for the test cases of optimal active flow control around a rotating cylinder and a NACA4412 airfoil.

Stephan Schmidt, Imperial College London

Large scale shape optimization

Shape optimization problems are a special sub-class of PDE constrained optimization problems. As such, they pose additional difficulties stemming from the need to compute derivatives with respect to geometry changes or variations of the domain itself. In addition to the adjoint methodology, this talk also considers how these derivatives with respect to the domain can be computed very efficiently. To this end, shape calculus is considered. The Hadamard theorem states that given sufficient regularity, the directional derivative of a shape optimization problem can be computed as a boundary scalar product with the normal component of the perturbation field and the shape gradient. Thus, knowledge of this shape gradient can be used to formulate an extremely fast optimization scheme, as tangential calculus can be used to derive gradient formulations that exist on the boundary of the domain only, thereby circumventing the need to know sensitivities of the mesh deformation inside the domain. Furthermore, approximate Newton methods can be employed in order to construct higher order optimization schemes. The Newton-type shape update can also be used to incorporate a desired boundary regularity

PDE-constrained opt. & multi-level/multi-grid meth.

Thu.3.MA 415

Variational methods in image processing and compressed sensing

Organizer/Chair Wotao Yin, Rice University · Invited Session

Yiqiu Dong, Helmholtz Zentrum Muenchen (with Tieyong Zeng)

A convex variational model for restoring blurred images with multiplicative noise

In this talk, we are concerned with a convex variational model for restoring blurred images with multiplicative noise. Based on the statistical property of the noise, a quadratic penalty technique is utilized in order to obtain a strictly convex model. For solving the optimization problem in the model, a primal-dual method is proposed. Numerical results show that this method can provide better performance of suppressing noise as well as preserving details in the image.

Hong Jiang, Bell Labs, Alcatel-Lucent (with Wei Deng, Zuowei Shen)

Surveillance video processing using compressive sensing

A compressive sensing method combined with decomposition of a matrix formed with image frames of a surveillance video into low rank and sparse matrices is proposed to segment the background and extract moving objects in a surveillance video. The video is acquired by compressive measurements, and the measurements are used to reconstruct the video by a low rank and sparse decomposition of matrix. The low rank component represents the background, and the sparse component is used to identify moving objects in the surveillance video. The decomposition is performed by an augmented Lagrangian alternating direction method. Experiments are carried out to demonstrate that moving objects can be reliably extracted with a small amount of measurements.

Tao Wu, Karl-Franzens-University of Graz (with Michael Hintermüller)

A nonconvex TV^q model in image restoration

A nonconvex variational model is introduced which contains ℓ_q -

norm, $q \in (0, 1)$, of image gradient as regularization. Such a regularization is a nonconvex compromise between support minimization and convex total-variation model. In finite-dimensional setting, existence of minimizer is proven, a semismooth Newton solver is introduced, and its global and locally superlinear convergence is established. The potential indefiniteness of Hessian is handled by a trust-region based regularization scheme. Finally, the associated model in function space is discussed.

Robust optimization

Thu.3.MA 004

Regret with robustness: Models, algorithms and applications

Organizer/Chair Karthik Natarajan, Singapore University of Technology and Design · Invited Session

Dongjian Shi, National University of Singapore (with Karthik Natarajan, Kim Chuan Toh)

A probabilistic model for minmax regret combinatorial optimization

We propose a probabilistic model for minimizing anticipated regret in combinatorial optimization problems with distributional uncertainty in the objective coefficients. The interval uncertainty representation of data is supplemented with information on the marginal distributions. As a decision criterion, we adopt a worst-case conditional value-at-risk of regret measure. The proposed model includes standard interval data minmax regret as a special case. For the class of combinatorial optimization problems with a compact convex hull representation, a polynomial sized mixed integer linear program (MILP) is formulated when (a) the range and mean are known, and (b) the range, mean and mean absolute deviation are known while a mixed integer second order cone program (MISOCP) is formulated when (c) the range, mean and standard deviation are known. For the subset selection problem, the probabilistic regret model is shown to be solvable in polynomial time for instances (a) and (b).

Andrew Lim, University of California (with George Shanthikumar, Gah-Yi Vahn)

Robust portfolio selection with learning in the framework of relative regret

We formulate single and multi-period portfolio choice problems with parameter uncertainty in the framework of relative regret. We solve the relative regret problem by showing that it is equivalent to a certain Bayesian problem which we analyze using stochastic control methods. The Bayesian problem is unusual in that the prior distribution is endogenously chosen, and the objective function involves the family of benchmarks from the relative regret problem. The solution of the Bayesian problem (and hence the relative regret problem) involves a "tilted" posterior, where the posterior comes from Bayesian updating of the endogenous prior, and tilting is defined in terms of a likelihood ratio that depends on the family of benchmarks.

Joline Uichanco, MIT (with Retsef Levi, Georgia Perakis)

Regret optimization for stochastic inventory models with spread information

We study a minimax regret approach to the newsvendor problem. Using a distribution statistic, called absolute mean spread (AMS), we introduce new families of demand distributions under the minimax regret framework. We propose order policies that only require a distribution's mean and information on the AMS. Our policies have several attractive properties. First, they take the form of simple closed-form expressions. Second, we can quantify an upper bound on the resulting regret. Third, under an environment of high profit margins, they are provably near-optimal under mild technical assumptions on the failure rate of the demand distribution. And finally, the information that they require is easy to estimate with data. We show in extensive numerical simulations that when profit margins are high, even if the information in our policy is estimated from (sometimes few) samples, they often manage to capture at least 99% of the optimal expected profit.

Sparse optimization & compressed sensing

Thu.3.H 1028

Variational signal processing – algorithms and applications

Organizer/Chair Junfeng Yang, Nanjing University · Invited Session

Wenxing Zhang, Nanjing University (with Michael K Ng, Xiaoming Yuan)

On variational image decomposition model for blurred images with missing pixel values

In this talk, we develop a decomposition model to restore blurred images with missing pixel values. Our assumption is that the true image is the superposition of cartoon and texture parts. We use the total variation (TV) norm to regularize the cartoon part and its dual norm to regularize the texture part, respectively. We recommend an efficient

numerical algorithm based on the variable splitting method to solve the problem. Theoretically, the existence of minimizer to the energy functional and the convergence of the algorithm are guaranteed. In contrast to recently developed methods for deblurring images, this algorithm not only gives the restored image, but also gives a decomposition of cartoon and texture parts. These two parts can be further used in segmentation and inpainting problems. Numerical comparisons between this algorithm and some state-of-the-art methods are also reported.

Junfeng Yang, Nanjing University (with Xin Liu, Yin Zhang)

Convergence of a class of stationary iterative methods for saddle point problems

The alternating direction method (ADM) was originally proposed in the 1970s. In the literature, very restrictive conditions, such as convexity of the objective function over the entire domain and separability into exactly two blocks, have been imposed to guarantee convergence of the ADM. Moreover, the convergence rate of ADM remains unclear. In this paper, we carry out a unified study on the convergence of a class of stationary iterative methods, which includes the ADM as a special case, for quadratic programming problems with linear equality constraints or linear saddle point problems. We establish global and q-linear convergence results without assuming convexity of the objective function and in the absence of separability of variables. Some numerical results are presented to support our findings, and extension to nonlinear saddle point problems is also discussed.

Yitun Wang, University of Electronic Science and Technology of China (with Wotao Yin)

Sparse signal reconstruction based on iterative support detection

We present a novel sparse signal reconstruction method based on iterative support detection (ISD, for short), aiming to achieve fast reconstruction and a reduced requirement on the number of measurements compared to the classical l_1 minimization approach. ISD addresses failed reconstructions of l_1 minimization due to insufficient measurements. It estimates a support set I from a current reconstruction and obtains a new reconstruction by solving a revised l_1 minimization problem, and it iterates these two steps for a small number of times. While introducing the general idea of ISD, we will present some recent thoughts about it.

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Stochastic optimization

Thu.3.MA 141

Measures of uncertainty

Organizer/Chair Marida Bertocchi, University of Bergamo · Invited Session

Francesca Maggioni, University of Bergamo (with Elisabetta Allevi, Marida Bertocchi)

Measures of information in multistage stochastic programming

Multistage stochastic programs, which involve sequences of decisions over time, are usually hard to solve in realistically sized problems. Providing bounds for their optimal solution, may help in evaluating whether it is worth the additional computations for the stochastic program versus simplified approaches. In this talk we generalize the value of information gained from deterministic, pair solutions and rolling-horizon approximation in the two-stage case to the multistage stochastic formulation. With respect to the former we introduce the Multistage Expected Value of the Reference Scenario, MEVRS, the Multistage Sum of Pairs Expected Values, MSPEV and the Multistage Expectation of Pairs Expected Value, MEPEV by means of the new concept of auxiliary scenario and redefinition of pairs subproblems probability. We show that theorems proved for two stage case are valid also in the multi-stage case. With respect to the latter, the rolling time horizon procedure allows to update the estimations of the solution at each stage. New measures of quality of the average solution are of practical relevance. Numerical results on a case study illustrate the relationships.

Simone Garatti, Politecnico di Milano (with Marco Campi, Algo Carè)

The risk of empirical costs in randomized min-max stochastic optimization

We consider convex min-max stochastic optimization. By sampling the uncertain parameter, the min-max solution that satisfies the sam-

pled instances of uncertainty can be constructed at low computational effort. This min-max solution incurs various costs, called “empirical costs”, in correspondence of the sampled instances of the uncertain parameter. Our goal is to precisely characterize the risks associated to the empirical costs, namely to evaluate the probability that the various empirical costs are exceeded when a new uncertainty instance is seen. The main result is that the risks distribute as an ordered Dirichlet distribution, irrespective of the probability measure of the uncertain stochastic parameter. This provides a full-fledged characterization of the reliability of the min-max sample-based solution.

Alexei Gaivoronski, Norwegian University of Science and Technology (with Paolo Pisciella)

Stochastic bilevel optimization problems with applications to telecom

We consider several stochastic bilevel optimization problems which have applications to supply chain management and information economics, where the system under consideration is composed from several independent actors. We consider solution methods that utilize analysis of analytical properties of the problem with stochastic optimization techniques.

Stochastic optimization

Thu.3.MA 144

Chance constrained stochastic optimization

Chair Yongjia Song, University of Wisconsin-Madison

Yongjia Song, University of Wisconsin-Madison (with Simge Küçükyavuz, James Luedtke)

A branch-and-cut algorithm for the chance-constrained knapsack problem

We consider a probabilistic version of classical 0-1 knapsack problem, where we have a set of items with random weight and a random knapsack capacity. The objective is to choose a set of items that maximizes profit while ensuring the knapsack constraint is satisfied with probability higher than a given threshold. We introduce a simple decomposition algorithm based on a probabilistic extension of cover inequalities to solve a sample average approximation (SAA) of this problem. We propose a probabilistic sequential lifting procedure to strengthen them, leveraging successful computational strategies for the deterministic knapsack problem. Exact lifting is hard, but we obtain an effective upper bound for the lifting problem using a scenario decomposition approach. Additional valid inequalities are proposed to further strengthen the bounds. A key advantage of our algorithm is that the number of branch-and-bound nodes searched is nearly independent of the number of scenarios used in the SAA, which is in stark contrast to formulations with a binary variable for each scenario.

Jessie Birman, Airbus Operation S.A.S.

Overall aircraft design based on chance-constrained programming

Preliminary Overall Aircraft Design (OAD) is classically carried out using a deterministic optimisation of a strategic criterion under operational constraints. The risk, which may appear all along the aircraft development, is mitigated by using a “margin philosophy” applied to some design parameters. A robustness study has highlighted the shortcomings of this way of doing, which does not offer the best protection possible against deviation to ensure requirement satisfaction. In the last decades, many researches have been done in the area of optimisation of complex processes under uncertainty. Attention has been put on methods reported in Stochastic Programming or Chance-Constrained Programming (CCP). The aim of the study is to propose a new methodology based on CCP to perform OAD. For this purpose, the main source of uncertainty affecting the system is identified and quantified. Then, a new formulation of the aircraft pre-design optimisation is stated according to the CCP framework. Particular attention is put on the choice of the objective function and the design parameters. This method is also used to assess the uncertainty involving an unconventional aircraft configuration.

Jianqiang Cheng, LRI, University of Paris-Sud (with Abdel Lisser)

Stochastic linear programming with joint chance constraints

This paper deals with a special linear programs with joint chance constraints, where the left-hand side of chance constraints is normally distributed stochastic coefficients and the columns s of the matrix are assumed independent to each other. We approximate this problem by solving its corresponding stochastic dual problem and there is a weak duality between them, i.e., the optimum objective value of the dual problem is a lower bound of the primal minimum problem. For the dual problem, it can be approximated by one SOCP problem. Furthermore, the optimum of the SOCP problem provides an upper bound of the dual problem. Finally, numerical experiments on random data are given to evaluate the approximation.

Telecommunications & networks

Thu.3.H 3002

Network design

Organizer/Chair Ridha Mahjoub, Université Paris-Dauphine · Invited Session

Viet Hung Nguyen, LIP6 - Université Pierre et Marie Curie Paris 6

A direct algorithm for detecting negative cost cycles in undirected graphs

Given an undirected, arbitrarily weighted graph $G = (V, E)$ with $n = |V|$ and $m = |E|$. We consider the problem of checking whether G contains a negative cost cycle (UNCCD). It is known that the corresponding problem in directed graphs (NCCD) can be solved by applying directly the Bellman-Ford algorithm. The UNCCD problem is much harder than the NCCD problem. In our knowledge, for solving the UNCCD, there is no direct algorithm and we should reduce it to either the b -matching problem or the T -join problem in some extended graphs derived from G . The latter reduction runs in $O(n^3)$ time while the former, running in $O(n^6)$ time, is less efficient. In this paper, we improve the time complexity by giving a direct algorithm for the UNCCD problem which runs in $O(mn + n^2 \log(n))$ time. The algorithm, which is based on a polyhedral characterization of the cone of circuit by Seymour, is a variant of Edmonds' blossom algorithm for matching.

Amal Benhamiche, Orange Labs/LAMSADE (with Ali Ridha Mahjoub, Nancy Perrot, Eduardo Uchoa)

On the optical multi-band network design problem

User demand in traffic is steadily increasing and telecommunication operators are now interested in high bandwidth capacitated networks to upgrade the transmission capacity of optical backbone networks. This evolution leads to a new variant of multi-layer network design problem: the optical multi-band network design (OMBND) problem. It consists in selecting the minimum number of subbands to install on the virtual layer so that the traffic can be routed and there exists a path in the physical layer associated to each subband. We propose a path formulation based on an implicit model for the problem and describe some additional valid inequalities. We then present a column generation procedure to solve the linear relaxation of OMBND that uses a two-stage pricing problem. The column generation procedure is embedded in a branch-and-price approach with a specific branching rule to derive an integer solution. Some computational results are presented for realistic instances of network and illustrate the efficiency of this approach to solve huge instances.

Raouia Taktak, LAMSADE / Université Paris-Dauphine (with Sylvie Borne, Virginie Gabrel-Willemin, A. Ridha Mahjoub)

Models and algorithms for the survivable multilayer network design problem

We are interested with the problem of survivability of the WDM layer in bilayer IP-over-WDM networks. Given a set of traffic demands for which we know a survivable logical routing in the IP layer, our purpose is to search the corresponding survivable topology in the WDM layer. We give two integer formulations for the problem. The first one uses cut constraints and the second is a path-based formulation. We discuss the polyhedron associated to the cut formulation and introduce some valid constraints. We also discuss the pricing problem and the branching strategy for the path formulation. We finally present primal heuristics and give some experimental results for the two formulations.

Telecommunications & networks

Thu.3.H 3503

Robust communication networks

Organizer/Chair Arie Koster, RWTH Aachen University · Invited Session

Grit Claßen, RWTH Aachen University (with Arie Koster, Anke Schmeink)

A branch-and-price approach for the robust wireless network planning

In this work, we consider the problem of base station location and traffic node assignment in wireless networks. The uncertainty by user behaviour is modelled by the well-known Γ -robustness approach by Bertsimas and Sim.

We compare a straightforward ILP with a column generation approach. The default ILP is divided into a restricted master problem and one pricing problem per base station. If a pricing problem finds an assignment variable with negative reduced cost fulfilling the capacity constraints, this variable is added to the restricted master problem. Since the pricing problems are robust knapsack problems, we can apply well-known techniques such as cover inequalities to improve the solving performance. Due to the integrality of all variables, we develop problem specific branching rules leading to a branch-and-price approach.

Finally, we present computational results comparing the branch-and-price formulation and the default ILP.

Peter Hoffmann, TU Chemnitz (with Christoph Helmberg)

Robust and chance constraint models of failure scenarios in the design of telecommunication networks

Given a backbone network for telecommunication with possibly uncertain demand between each pair of nodes, the task is to find capacities for the edges in the network so that all demand can be routed through the network. We consider here failure scenarios where nodes or edges may fail. In the single failure scenario a standard approach is to require the presence of a node disjoint cycle for each pair of nodes, so that in case of failure there still is a path between each two intact nodes. In this study we want to exploit the differing probabilities of the failure of network items (nodes or edges), so that even in the case of two or more failures the probability that more than a prespecified value of demand is unroutable is kept below a given level. If the failure probabilities follow a normal distribution this leads to a model with a chance constraint, that couples the node and edge failures and the resulting loss in routable demand. An implementable variant is based on a semidefinite relaxation of bilinear terms and a second order cone constraint replacing the chance constraint.

Daniel Karch, TU Berlin (with Andreas Bley, Fabio d'Andreagiovanni)

Fiber replacement scheduling

During the operation of large telecommunication networks, it is sometimes necessary to replace components in a big part of a network. Since a network resource, such as a router or an optical fiber cable, is usually in shared use by several connections, all of these connections will have to be shut down while the component is being replaced. Since the number of workers that perform the upgrade is limited, not all of the affected connections can be upgraded at the same time, and disruptions of service cannot be avoided. Our goal is to schedule the replacement of the fibers in such a way, that the number of workers necessary in each period of the discretized planning horizon does not exceed the given budget, and the sum of all connections' disruption times is minimized. We will present exact mathematical formulations for the problem, discuss its connection to the linear arrangement problem, and give first results on the hardness of approximation.

Variational analysis

Thu.3.H 2035

Set-valued convex and quasiconvex duality

Organizer/Chair Andreas Hamel, Yeshiva University New York · Invited Session

Carola Schrage, University of Halle, Wittenberg (with Giovanni Crespi, Andreas Hamel)

Dini derivatives for vector- and set-valued functions

We will introduce set-valued derivatives of Dini type for vector- and set-valued functions and provide basic calculus rules for these derivatives. Using a solution concept for multicriteria optimality problems introduced by Heyde and Löhne in 2008, we will provide a variational principle of Minty type supplying necessary and sufficient optimality conditions and state a Fermat rule, a necessary condition under which a subset of the pre-image space is a solution to the given optimality problem.

Andreas Hamel, Yeshiva University New York (with Andreas Löhne)

Lagrange duality in set optimization

A Lagrange type duality theorem for set-valued optimization problems is presented. New features include set-valued Lagrangians and saddle set (rather than point) theorems based on infima and suprema in appropriate spaces of sets. An application to multivariate utility maximization is given.

Samuel Drapeau, Humboldt University Berlin (with Andreas Hamel, Michael Kupper)

Complete duality for convex and quasiconvex set-valued functions

The Fenchel-Moreau theorem is a central result stating a one to one relation between l.s.c. convex functions and their conjugate. For quasiconvex functions, a dual representation has been achieved by Penot, Volle. The complete duality, that is, the unique characterisation of the dual function, has been done by Cerreia-Voglio et al. on M -spaces and Drapeau, Kupper on lctvs. However, for vector valued convex functions problems appear for the existence of a Fenchel-Moreau theorem and the uniqueness is still open.

In this talk, we present a complete duality for quasiconvex and convex set valued functions. More precisely, given a l.s.c. quasiconvex function $F : X \rightarrow \mathcal{P}(Z, K)$ where $\mathcal{P}(Z, K)$ is the set of monotone subsets of a vector space Z with respect to a convex cone K , then, there exists a function $R : X^* \times \mathbb{R} \rightarrow \mathcal{P}(Z, K)$ such that

$$F(x) = \sup_{x^*} R(x^*t, x^*(x)).$$

Furthermore, R is uniquely determined if $K \setminus (-K) \neq \emptyset$. For convex functions we provide a set-valued pendant to the Fenchel Moreau theorem. As an illustration, we study the dual representation of non complete preference orders.

Variational analysis

Thu.3.H 2051

Semi-continuous programming

Organizer/Chair Wilfredo Sosa, Catholic University of Brasilia · Invited Session

Ademir Ribeiro, Federal University of Paraná (with John Cotrina, Elizabeth Karas, Wilfredo Sosa, Yuan Yun)

Fenchel-Moreau conjugation for lower semi-continuous functions

We introduce a modification of Fenchel's conjugation which is a particular case of Moreau's conjugation. We obtain nice properties as convexity of the conjugate function even though the function is not convex. We also introduce the concept of conjugate dual space as a class of continuous operators, while in the Fenchel's conjugation, the conjugate dual space is the classical topological dual space. Finally we present some examples for illustrating the difference between the Fenchel-Moreau's conjugation and our modification.

Fernanda Raupp, PUC-Rio (with John Cotrina, Wilfredo Sosa)

A duality scheme for semi-continuous programming

We introduce a duality scheme for the class of mathematical programming problems called Semi-Continuous Programming (SCP), which contains constrained minimization problems with lower semi-continuous objective functions. We study some solution existence conditions for SCP based on asymptotic techniques. Then, we devise the duality scheme for the SCP problem through the construction of an auxiliary function and the application of a modification of the Fenchel-Moreau conjugation. We show that the dual problem associated to the SCP problem is convex and, particularly, we devise a dual problem for the minimization of any quadratic function constrained to a polyhedral set.

Wilfredo Sosa, Catholic University of Brasilia

Separation theorems for closed sets

In this paper we introduce some separation theorems for disjoint closed nonempty sets. The proposed theoretical results differ from the ones in the literature, in particular from Urisohn's and Michael's results, mainly by making use of special continuous functions (in fact, this class of special continuous functions is a dense subspace of the continuous functions space with the domain being a Hilbert space and real values) instead of considering just the space of all these continuous functions. As an application we reconstruct the conjugation for lower semi-continuous functions.

Approximation & online algorithms

Fri.1.H 3010

Approximation of vehicle routing problems

Chair Ignacio Vargas, Diego Portales University

Martijn van Brink, Maastricht University (with Alexander Grigoriev, Tjark Vredeveld)

Express delivery of packages

We consider a capacitated, fixed-charge, multicommodity flow problem with indivisible commodities. The commodities are transported with trucks, which all have the same capacity, and we assume there is an unlimited number of trucks. We show that, unless P=NP, there cannot exist a polynomial time $O(\log K)$ -approximation algorithm, where K is the number of commodities. Applying randomized rounding, we obtain an approximation ratio of $K+1$, and we show that this ratio is tight. Next, we restrict the underlying network to cycles. We prove that the problem remains NP-hard and we develop a 4-approximation. If we assume that the total volume of all commodities is at most the capacity of a single truck, we get an integer linear programming formulation with a totally unimodular constraint matrix. Thus, we can obtain the optimal solution in polynomial time. Finally, we consider the case where we have a fixed number of commodities, and show that for 2 and 3 commodities the problem can be also solved in polynomial time.

Ignacio Vargas, Diego Portales University (with Juan Sepulveda, Oscar Vasquez)

An efficient decision making process for vehicle operations in underground mining based on a mixed-integer programming model

Mining operations can be seen as a vertically positioned threefold process: production, reduction and transportation. The workload of levels are pushed top-down by a plan-driven strategy, that contains the number of ore bucketfuls to be extracted at the production level. Unfortunately, the goal of minimizing makespan in the production level would be not always optimal when taking into consideration the coordination

levels. In this paper, a mixed integer programming model to minimize makespan of drift workload subject to the coordination between production and reduction levels is formulated. The problem NP-hardness in strict sense is proved, the value of 2 as upper bound for polynomial algorithm in the off and on-line case is given, and 1.25-approximation algorithm for its resolution is proposed. Next, a set of decision rules obtained from the above algorithm is integrated into a simple-to-execute decision making process for LHD operators. Currently, a numerical analysis based on Chilean underground copper mine *El Teniente* data is being realized to explore the practical potential of the DMP proposed. The preliminary results show an average value 1.08.

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Combinatorial optimization

Fri.1.H.3004

Approximation algorithms for hard problems

Organizer/Chair Guochuan Zhang, Zhejiang University · Invited Session

Lin Chen, University of Kiel (with Klaus Jansen, Wenchang Luo, Guochuan Zhang)

Approximation algorithms for scheduling parallel machines with capacity constraints

In this paper, we consider the classical scheduling problem on parallel machines with capacity constraints. We are given m identical machines, where each machine k can process up to c_k jobs. The goal is to assign the $n \leq \sum_{k=1}^m c_k$ independent jobs on the machines subject to the capacity constraints such that the makespan is minimized. This problem is a generalization of c -partition, which is strongly NP-hard for $c \geq 3$ and the best known approximation algorithm of which has a performance ratio of $4/3$ due to Babel et al..

We deal with the general problem and improve the previous results by establishing an efficient polynomial time approximation scheme (EPTAS) whose running time is at most $2^{O(1/\epsilon^2 \log^3(1/\epsilon))} + \text{poly}(1/\epsilon, \log n) + O(n \log n)$. We develop a best-fit schedule for small jobs, and then handle the assignment of big jobs through a mixed integer programming (MILP). Such an MILP consists of a huge number of integer variables which is not even a constant, however, we would provide a greedy rounding technique to modify it iteratively so that the number of its integer and fractional variables is sharply reduced.

Guangting Chen, Hangzhou Dianzi University (with Yong Chen, An Zhang)

Approximation algorithms for parallel open shop scheduling

This paper investigates a new scheduling problem, namely the parallel open shop scheduling. In this problem, each job consists of two operations, which must be non-preemptively processed by one of the m two-stage parallel open shops. The objective is to minimize the makespan. As the problem is NP-hard, we provide the first approximation algorithm with a worst case ratio of 2 for m machines, and for $m = 2$, an improved algorithm with worst case ratio $3/2$ is further proposed. Both algorithms run in $O(n \log n)$ time.

Xudong Hu, Academy of Math and Systems Science, Chinese Academy of Sciences (with E.

Alvarez-Miranda, Xujin Chen, Jie Hu, Bi Li)

New models for network connection problems with interval data

In this talk, I will present a new approach for dealing with network connection problems with uncertain parameters, where, it is assumed, cost on a link/node in a given network fall into an interval. We introduced two risk models for these problems, proposed polynomial-time algorithms for solving the problems and conducted computational experiments on algorithms proposed. Our theoretical and computational results show the flexibility of this new approach for decision makers at

different levels of aversion to risk, as well as satisfactory performance of standard CPLEX solver on our model.

Combinatorial optimization

Fri.1.H.3005

Combinatorial optimization in logistics

Organizer/Chair Erwin Pesch, University of Siegen · Invited Session

Jens Schulz, TU Berlin (with Stefan Heinz)

Explanation algorithms in cumulative scheduling

In cumulative scheduling, conflict analysis is one of the key ingredients to solve these problems efficiently. Thereby, the computational complexity of explanation algorithms that explain infeasibilities or bound changes plays an important role. Their role is even more substantial when we are faced with a backtracking system where explanations need to be constructed on the fly. In this talk we present complexity results for computing minimum-size explanations for the propagation algorithms time-tabling, edge-finding, and energetic reasoning. We show that it is possible to compute in polynomial time minimum-size explanations for bound changes which result from energetic reasoning and edge-finding. In case of time-tabling, we prove that an important special case is already weakly NP-hard. In the context of bound-widening, the problems all become NP-hard. To this end, we establish a relation to unsplittable flow problems on the path. We evaluate different heuristic approaches and exact approaches to explain bound changes derived by these algorithms. Using these minimum-size explanations pays off in total compared to using faster but weaker explanation algorithms.

Jenny Nossack, University of Siegen (with Erwin Pesch)

Benders decomposition for a 1-full-truckload pickup-and-delivery vehicle routing problem

We address a pickup and delivery vehicle routing problem with multiple depots, where routes have to be constructed to satisfy customer requests, which either involve the pickup or delivery of a single commodity. A fleet of homogeneous vehicles is available to fulfill the demand and supply of the customers under the objective to minimize the total distance traveled. Each vehicle has unit capacity and the commodities which are collected from the pickup customers can be used to accommodate the demand of the delivery customers. We model this problem as an integrated integer nonlinear programming problem that simultaneously solves an assignment and a routing problem, linked via coupling constraints. Exact solution approaches based on the classical and the generalized Benders decomposition are presented to optimally solve the problem.

Erwin Pesch, University of Siegen (with Jenny Nossack)

A branch-and-bound algorithm for the acyclic partitioning problem

We focus on the problem of partitioning the vertex set of a directed, arc- and vertex-weighted graph into clusters, i.e. disjoint sets. Clusters are to be determined such that the sum of the vertex weights within the clusters satisfies an upper bound and the sum of the arc weights within the clusters is maximized. Additionally, the graph is enforced to partition into a directed, acyclic graph where the clusters define the vertices. This problem is known as the acyclic partitioning problem and has been proven to be NP-hard. Real-life applications arise at rail-rail transshipment yards. We propose new integer programming formulations for the acyclic partitioning problem and suggest an exact solution approach based on an integration constraint propagation into a branch-and-bound framework. Computational results are reported to confirm the strength of our approach.

Combinatorial optimization

Fri.1.H.3008

Algorithms in claw-free graphs

Organizer/Chair Gautier Stauffer, University Bordeaux 1 – INRIA · Invited Session

Matthias Mnich, MCCI / Max-Planck-Institute for Computer Science (with Danny Hermelin, Erik Jan Leeuwen, Gerhard Woeginger)

Domination when the stars are out - Efficient decomposition of claw-free graphs

We algorithmize the recent structural characterization for claw-free graphs by Chudnovsky and Seymour. Building on this result, we show that several domination problems are fixed-parameter tractable, and even possess polynomial-sized kernels, on claw-free graphs. To complement these results, we establish these problems are not fixed-parameter tractable on the slightly larger class of graphs that exclude $K_{1,4}$ as an induced subgraph. Our results provide a dichotomy for $K_{1,L}$ -

free graphs and characterize when the problems are fixed-parameter tractable.

Yuri Faenza, Università di Padova (with Gianpaolo Oriolo, Gautier Stauffer)

Separating stable sets in claw-free graphs through extended formulations

The stable set polytope in claw-free graphs (ssp-cf) is a well-known generalization of the matching polytope. A linear description of the latter only requires rank inequalities (i.e., with 0/1 coefficients), while the associated separation problem can be solved via a purely combinatorial routine. For ssp-cf the situation is quite different: no complete description is known, and there exist examples of facets with arbitrarily high coefficients. Moreover, the only known separation routine relies on the ellipsoid method.

In this talk, we provide linear programming extended formulations for ssp-cf, together with polynomial time separation routines for those formulations (they are not compact). Those formulations rely on combinatorial optimization, polyhedral combinatorics, and structural graph theory results. We then exploit one of those extended formulations to propose a new polytime algorithm for solving the separation problem for ssp-cf. This routine combines the separation algorithm for the matching polytope and the solution of (moderate size) compact linear programs, hence it does not require the application of the ellipsoid method.

Paolo Nobile, Università del Salento (with Antonio Sassano)

A decomposition algorithm for the weighted stable-set problem in claw-free graphs

In this paper we describe a new characterization of a *line-graph* $G(V, E)$ in terms of forbidden substructures. Unlike the classical characterization due to Bermond and Meyer based on forbidden induced subgraphs, we rely upon the properties of a suitable maximal stable set S of G . Following Lozin, we say that two nodes u and v in $V \setminus S$ are *similar* if $N(u) \cap S = N(v) \cap S$. Moreover, extending a definition due to Schrijver, we say that a node $s \in S$ is *clique-splittable* in G with respect to S if the nodes in $N(s)$ can be partitioned in two cliques (X_s, Y_s) with the property that each dissimilar pair of nodes z, y in $N(s)$ is adjacent if and only if both belong to X_s or Y_s . Our main result is that a claw-free graph G is a line graph if and only if each node $s \in S$ is clique-splittable and S does not define two special structures in G , namely a pair of *cross-linked* nodes or a *free-strip*.

Combinatorial optimization

Fri.1.H 3012

Cliques, stable sets, and perfect graphs

Chair Graciela Nasini, Universidad Nacional de Rosario

Maribel Montenegro, Escuela Politécnica Nacional

On the N -index of the stable set polytope related to antiwebs

In this work we investigate the application of the N and N_+ operators, defined by Lovász and Schrijver (1990), to the edge relaxation of the stable set polytope related to antiwebs. The first immediate result is that these polytopes have N_+ -index equal to 1.

Moreover, we have proved that if an antiweb \overline{W}_n^k is such that $n = qn' + 1$ and $k = q(k' + 1) - 1$ with $n', k', q \in \mathbb{N}$ and $q \geq 2$, it contains a subantiweb which is isomorphic to the antiweb $\overline{W}_{n'}^{k'}$, and the rank constraint of this subantiweb can be used to generate the rank constraint of \overline{W}_n^k . Using this construction we obtain upper-bounds on the N -index for some particular classes of antiwebs.

Graciela Nasini, Universidad Nacional de Rosario

Lovász-Schrijver $N_+(\cdot)$ relaxations on the fractional stable set polytope in a superclass of near-perfect graphs

N_+ -perfect graphs are those graphs for which its stable set polytope is achieved by applying Lovász and Schrijver's N_+ operator on its edge relaxation once. They define a proper superclass of perfect graphs where the Maximum Weight Stable Set Problem is solvable in polynomial time. In this sense, it would be worth it to have good characterizations of this graph class. A graph is nb-perfect if the support graph of every facet defining inequality of its stable set polytope is near-bipartite. It is known that nb-perfect graphs constitute a subclass of N_+ -perfect graphs. In a previous work, we handled the question whether any N_+ -perfect graph is an nb-perfect graph and we proved it is true when restricted to near-perfect graphs. In this work we extend this result to the proper superclass of near-perfect graphs defined by those graphs for which its stable set polytope is described by the clique constraints and at most one full support inequality. We also prove that any graph ob-

tained by applying the clique subdivision operation on an N_+ -imperfect graph cannot be N_+ -perfect.

Claudia Snels, Università di Roma Tor Vergata (with Flavia Bonomo, Gianpaolo Oriolo)

Minimum weighted clique cover on strip-composed perfect graphs

On a perfect graph G where a non negative weight function on the vertices $w : V \rightarrow \mathbb{R}^+$ is given, the *minimum weighted clique cover* problem (MWCC), consists on finding a collection of cliques \mathcal{C} , each one with a non-negative value $y_{\mathcal{C}}$, such that for every vertex $v \in \sum_{\mathcal{C} \in \mathcal{C}: v \in \mathcal{C}} y_{\mathcal{C}} \geq w(v)$ and the weight $\sum_{\mathcal{C} \in \mathcal{C}} y_{\mathcal{C}}$ is minimum.

The only available combinatorial algorithm for the MWCC in claw-free perfect graphs is due to Hsu and Nemhauser and dates back to 1984. More recently, Chudnovsky and Seymour in 2005 introduced a composition operation, strip-composition, in order to define their structural results for claw-free graphs; however, this composition operation is general and applies to non-claw-free graphs as well.

In this paper, we show that a MWCC of a perfect strip-composed graph, with the basic graphs belonging to a class \mathcal{G} , can be found in polynomial time, provided that the MWCC problem can be solved on \mathcal{G} in polynomial time. We also design a new, more efficient, combinatorial algorithm for the MWCC problem on strip-composed claw-free perfect graphs.

Combinatorial optimization

Fri.1.H 3013

Extended formulations

Chair Ralf Borndörfer, Zuse Institute Berlin

Paolo Serafini, University of Udine - Italy (with Giuseppe Lancia)

Compact formulations for large-scale LP problems

There are many combinatorial problems which can be effectively dealt with via Integer Linear Programming by using column-generation or constraint-generation techniques. When the pricing for column generation can be solved by Linear Programming, it is possible to embed the positive reduced cost condition into the dual of the relaxed integer primal. Similarly, for constraint generation, if the separation problem is a Linear Program, it can be embedded into the integer primal. The new model has polynomial size and has the same lower bounds as the original exponential size model. We call "compact" this reformulation. The compact reformulation may provide new insight into the problem structure and sometimes exhibits a computational better performance than the original formulation. It is possible to develop compact models for the following problems: Bin packing, Max cut, Stable set, TSP, Minimum routing cost tree, Steiner tree, Cycle packing, Alternate cycle decomposition, Job Shop, Protein fold comparison and various variant of TSP, like Prize collecting TSP and Time window TSP.

Achim Hildenbrandt, Universität Heidelberg (with Olga Heismann, Gerhard Reinelt)

An extended formulation for the target visitation problem

The target visitation problem (TVP) is concerned with finding a route to visit a set of targets starting from and returning to some base. In addition to the distance traveled, a tour is evaluated also by taking preferences into account addressing the sequence in which the targets are visited. The problem thus is a combination of two well-known combinatorial optimization problems: the traveling salesman and the linear ordering problem. The TVP was introduced to serve the planning of routes for unmanned aerial vehicles (UAVs) and it can be employed to model several kinds of routing problems with additional restrictions. In this talk we want to point out some properties of the polyhedral structure of an associated polytope and also present an extended formulation. We will use this formulation to develop a branch-and-price algorithm. Computational results will be discussed.

Ralf Borndörfer, Zuse Institute Berlin (with Olga Heismann, Marika Karbstein, Markus Reuther, Thomas Schlechte, Steffen Weider)

Configuration models for solving integrated combinatorial optimization problems

The talk proposes configuration models as an effective approach to combinatorial optimization problems that integrate several types of constraints. Configurations are local building blocks of primal solutions. They can be used to express complex requirements, that would be difficult to formulate in terms of constraints, using an exhaustive, but local, and hence manageable, enumeration of variables. This often gives rise to large, but combinatorially clean packing and covering type models, and it often produces strong LP bounds. Configuration models can be seen as an approach to construct extended formulations; these, in turn, lend themselves to column generation methods. Examples of successful applications of this method include railway track allocation (the configurations are occupations of track segments over time), vehicle rotation planning (the configurations correspond to train compositions), and line planning (configurations correspond to line bundles on an infrastructure segments).

Complementarity & variational inequalities

Fri.1.MA 313

Algorithms for complementarity and related problems II

Chair Goran Lesaja, Georgia Southern University

Mauro Passacantando, University of Pisa (with Giancarlo Bigi)

Gap functions and penalization for solving equilibrium problems with nonlinear constraints

Several descent methods for solving equilibrium problems (EPs) have been recently proposed. They are based on the reformulation of EP as a global optimization problem through gap functions. Most approaches need to minimize a convex function over the feasible region in order to evaluate the gap function, and such evaluation may be computationally expensive when the feasible region is described by nonlinear convex inequalities. In this talk we introduce a new family of gap functions which rely on a polyhedral approximation of the feasible region rather than on the feasible region itself. We analyze some continuity and generalized differentiability properties and we prove that monotonicity type assumptions guarantee that each stationary point of a gap function is actually a solution of EP. Finally, we proposed two descent algorithms for solving EPs. Unlike most of the available algorithms, we consider a search direction which could be unfeasible, so that the use of an exact penalty function is required. The two algorithms differ both for the updating of regularization and penalization parameters and for the assumptions which guarantee their global convergence.

Goran Lesaja, Georgia Southern University

Infeasible full-Newton step interior-point method for linear complementarity problems

We present an infeasible Full-Newton-Step Interior-Point Method for Linear Complementarity Problems. The advantage of the method, in addition to starting from an infeasible starting point, is that it uses full Newton-steps, thus avoiding the calculation of the step size at each iteration. However, by suitable choice of parameters iterates are forced to stay in the neighborhood of the central path, thus, still guaranteeing the global convergence of the method. The number of iterations necessary to find epsilon-approximate solution of the problem matches the best known iteration bounds for these types of methods.

Conic programming

Fri.1.H 2036

Algebraic geometry and conic programming I

Organizers/Chairs Lek-Heng Lim, University of Chicago; Cordian Riener, University of Konstanz · Invited Session

Tim Netzer, University of Leipzig (with Daniel Plaumann, Andreas Thom)

Describing the feasible sets of semidefinite programming

The feasible sets of semidefinite programming, sometimes called spectrahedra, are affine slices of the cone positive semidefinite matrices. For a given convex set it might however be quite complicated to decide whether it is such a slice or not. Alternative characterizations of spectrahedra are thus highly desirable. This interesting problem turns out to be related to algebra, algebraic geometry and non-commutative geometry. I will explain some of the recent developments in the area.

Sabine Burgdorf, École Polytechnique Fédérale de Lausanne (with Kristijan Cafuta, Igor Klep, Janez Povh)

Lasserre relaxation for trace-optimization of NC polynomials

Given a polynomial f in noncommuting (NC) variables, what is the smallest trace $f(\mathbf{A})$ can attain for a tuple \mathbf{A} of symmetric matrices? This is a nontrivial extension of minimizing a polynomial in commuting variables or of eigenvalue optimization of an NC polynomial – two topics with various applications in several fields. We propose a sum of Hermitian squares relaxation for trace-minimization of an NC polynomial and its implementation as an SDP. We will discuss the current state of knowledge about this relaxation and compare it to the behavior of Lasserre relaxations for classical polynomial minimization and for eigenvalue optimization respectively.

Raman Sanyal, Freie Universität Berlin (with Avinash Bhardwaj, Philipp Rostalski)

Deciding polyhedrality of spectrahedra

Spectrahedra, the feasible regions of semidefinite programs, form a rich class of convex bodies that properly contains that of polyhedra. It is a theoretical interesting and practically relevant question to decide when a spectrahedron is a polyhedron. In this talk I will discuss how this can be done algorithmically by making use of the geometry as well as the algebraic structure of spectrahedra.

Conic programming

Fri.1.H 2038

Recent developments of theory and applications in conic optimization II

Organizers/Chairs Hayato Waki, Kyushu University; Masakazu Muramatsu, The University of Electro-Communications · Invited Session

Mirai Tanaka, Tokyo Institute of Technology (with Kazuhide Nakata, Hayato Waki)

Numerical computation of a facial reduction algorithm and an inexact primal-dual path-following method for doubly nonnegative optimization problems

In this talk, we introduce an effective approach to solve doubly nonnegative relaxation (DNR) problems for mixed binary nonconvex quadratic optimization problems. In our approach, we convert a given DNR problem into another one that is smaller than the original one exploiting degeneracy. We can expect numerical stability of interior-point methods for the DNR problem to be improved because this conversion can be regarded as an incomplete facial reduction algorithm. In a previous approach, we can find degeneracy only relevant to semidefiniteness analytically. In our approach, to also find degeneracy relevant to non-negativity, we compute a dense optimal solution of a linear optimization problem with an interior-point method. Moreover, we propose an inexact primal-dual path-following method for the reduced DNR problems. In our algorithm, to compute search directions, we solve large linear systems via the preconditioned symmetric quasi-minimal residual (PSQMR) method. To accelerate the convergence of the PSQMR method, we develop some preconditioners. Numerical results show that we can solve some instances of DNR problems quickly and accurately.

Matsukawa Yasuaki, University of Tsukuba (with Yoshise Akiko)

A primal barrier function phase I algorithm for nonsymmetric conic optimization problems

We call the set of positive semidefinite matrices whose elements are nonnegative the doubly nonnegative (DNN) cone. The DNN cone can be represented as a projection of a symmetric cone given by the direct sum of the semidefinite cone and the nonnegative orthant. Using the symmetric cone representation, the authors demonstrated the efficiency of the DNN relaxation and showed that it gives significantly tight bounds for a class of quadratic assignment problems while the computational time is too long. The result suggests a primal barrier function approach for the DNN optimization problem. However, most of existing studies on the approach have assumed the availability of a feasible interior point which is not practical. Motivated by these observations, we propose a primal barrier function Phase I algorithm for solving conic optimization problem over the closed convex cone K such that (a) K is not necessarily symmetric, (b) a self-concordant function is defined over the interior of K , and (c) its dual cone is not explicit or is intractable, all of which are observed when K is the DNN cone. We analyze the algorithm and provide a sufficient condition for finite termination.

Victor Magron, École Polytechnique INRIA (with Xavier Allamigeon, Stéphane Gaubert, Benjamin Werner)

Certification of inequalities involving transcendental functions using semi-definite programming.

We consider the optimization problem $\min_{x \in K} f(x)$, where f is a multivariate transcendental function and K is a compact semi-algebraic set. Recent efforts have been made to produce positivity certificates for these problems, and to verify these certificates with proof assistants such as Coq. Our motivation is to automatically verify inequalities from the proof of Kepler conjecture by Thomas Hales.

We will present a certification framework, combining semi-definite programming with semi-algebraic approximations of transcendental functions. Our method consists in an iterative decomposition of the set K into subsets in which the inequalities to be certified are expected to be either tight or coarse. Coarse inequalities are checked by global optimization methods (solving a hierarchy of relaxed problems using SOS solvers such as SparsePOP). Then, the feasible points generated by these methods are used to refine iteratively the semi-algebraic approximations of transcendental functions until the needed accuracy is reached. Tight inequalities are certified locally by Taylor-type models. Experimental results will illustrate numerical and scalability issues.

Derivative-free & simulation-based opt.

Fri.1.H 3003A

MINLP and constrained optimization without derivatives

Organizers/Chairs Stefan Wild, Argonne National Laboratory; Luis Nunes Vicente, University of Coimbra · Invited Session

Francisco Sobral, Itau Unibanco Holding SA (with José Mario Martínez)

Constrained derivative-free optimization on thin domains

Many derivative-free methods for constrained problems are not ef-

efficient for minimizing functions on “thin” domains. Other algorithms, like those based on Augmented Lagrangians, deal with thin constraints using penalty-like strategies. When the constraints are computationally inexpensive but highly nonlinear, these methods spend many potentially expensive objective function evaluations motivated by the difficulties in improving feasibility. An algorithm that handles this case efficiently is proposed in this paper. The main iteration is split into two steps: restoration and minimization. In the restoration step, the aim is to decrease infeasibility without evaluating the objective function. In the minimization step, the objective function f is minimized on a relaxed feasible set. A global minimization result will be proved and computational experiments showing the advantages of this approach will be presented.

Juliane Müller, Tampere University of Technology (with Robert Piché, Christine Shoemaker)

A surrogate model algorithm for computationally expensive mixed-integer black-box global optimization problems

We present a surrogate model algorithm for computationally expensive mixed-integer black-box global optimization problems that may have computationally expensive constraints. The goal is to find accurate solutions with relatively few function evaluations. A radial basis function surrogate model is used to select candidates for integer and continuous decision variable points at which the computationally expensive objective and constraint functions are to be evaluated. In every iteration multiple new points are selected based on different methods, and the objective and constraint functions are evaluated in parallel. The algorithm converges to the global optimum almost surely. The performance of this new algorithm (SO-MI) is compared to a branch and bound algorithm for nonlinear problems, a genetic algorithm, and the NOMAD (Nonsmooth Optimization by Mesh Adaptive Direct Search) algorithm for mixed-integer problems on test problems from the literature, and application problems arising from structural optimization. The numerical results show that SO-MI reaches significantly better results than the other algorithms.

Joshua Griffin, SAS (with Steven Gardner)

A parallel hybrid derivative-free SAS procedure for MINLP

We present a new parallel derivative-free SAS procedure for mixed-integer nonlinear black-box optimization. The solver is motivated by recent work on the EAGLS (Evolutionary Algorithms Guiding Local Search) algorithm developed for simulation-based groundwater optimization problems. The SAS procedure makes minimal assumptions on the structure of the nonlinear objective/constraint functions; they may be discontinuous, noisy, and expensive to evaluate. Integer variables are handled by running multiple genetic algorithms concurrently. In addition to crossover and mutation, a “growth step” permits selected members of the population (based on fitness and diversity) to benefit from local optimization over the real variables. For local search algorithms normally limited to real variables, this provides a simple framework for supporting integer variables that fits naturally in a parallel context. Load imbalance is exploited by both global and local algorithms sharing evaluation threads running across multiple processors. Unique evaluations are cached. Linear constraints are handled explicitly using tangent search directions and the SAS/OR OPTLP procedure.

Finance & economics

Fri.1.H 3021

Portfolio selection problems

Chair Marius Radulescu, Institute of Mathematical Statistics and Applied Mathematics

Constanta Radulescu, National Institute for Research and Development in Informatics (with Marius Radulescu, Sorin Radulescu)

Portfolio selection models with complementarity constraints

We extend Markowitz’s portfolio selection model to include transaction costs in the presence of initial holdings for the investor. Our approach is new. Our aim is to obtain an optimal portfolio which has a minimum risk or a maximum return. Our portfolio selection models include complementarity constraints. This type of constraints increases the difficulty of the problems, which now enter in the category of combinatorial optimization problems. The set of feasible solutions for the problems from the above mentioned class is the union of a set of convex sets but it is no longer convex. We give an algorithm for finding solutions of portfolio selection models with complementarity constraints. Several numerical results are discussed.

Marius Radulescu, Institute of Mathematical Statistics and Applied Mathematics (with Constanța Radulescu, Sorin Radulescu)

The efficient frontiers of mean-variance portfolio selection problems

In the paper are defined the notions of efficient frontier set and efficient frontier function of a parametric optimization problem. We formulate several portfolio selection problems which are nonlinear programming problems. Two of them are minimum variance type problems

and the other two are maximum expected return type problems. Taking into account various hypotheses on the covariance matrix and on the vector of means the duality between minimum variance type problems and maximum expected return type problems is investigated. We are interested when the efficient frontier sets of the minimum variance type problems and of the maximum expected return type problems are equal. Generalization of the problems studied to the case of mean-risk models is suggested.

Finance & economics

Fri.1.H 3027

Optimal control

Chair Yuichi Takano, Tokyo Institute of Technology

Arindum Mukhopadhyay, Indian Institute of Technology, Kharagpur (with Adrijit Goswami)

A socio-economic production quantity (SEPPQ) model for imperfect items with pollution control and varying setup costs

Corporate social responsibility (CSR) initiatives have gained considerable prominence in recent years. Public demand for environmental protection has created a need for identifying the most ecofriendly and economic production strategies. Keeping this in mind, this paper investigates a socioeconomic production quantity (SEPPQ) model with imperfect quality items for varying setup cost using the setup cost as a function of production run length. The setup cost and run length can be related in terms of process deterioration and learning and forgetting effects. Three different approaches of minimizing pollution during production process and transportation is provided. Mathematical models and solution procedures are developed for each of them. Numerical example and sensitivity analysis are provided to illustrate and analyse the model performance. It is observed that our model has a significant impacts on the optimal lot size and optimal profit of the model.

Yuichi Takano, Tokyo Institute of Technology (with Jun-Ya Gotoh)

Control policy optimization for dynamic asset allocation by using kernel principal component analysis

We utilize a nonlinear control policy, which is a function of past asset returns or economic indicators, to construct a portfolio. Although the problem of selecting the best control policy from among nonlinear functions is intractable, our previous study has built a computational framework for solving this problem. Specifically, we have shown that this problem can be formulated as a convex quadratic optimization problem by using a kernel method, which is an engine for dealing with the strong nonlinearity of statistical models in machine learning. Our nonlinear control policy resulted in better investment performance than the basic model and linear control policies could give. However, it was difficult to handle a large-scale portfolio optimization problem. Thus in this presentation, we provide an efficient solution for optimization of a nonlinear control policy by using kernel principal component analysis. Computational experiments show that our solution is effective not only in reducing the CPU time but also in improving the investment performance.

Vasily Dikumar, Dorodnicyn Computing Centre (with Nikolay Olenov)

An optimal control problem in estimation of parameters for economic models

Each mathematical model of economy contains a lot of unspecified parameters which are not defined directly by the data of economic statistics. We determine the unknown parameters of an economic model by comparing time series for macro indexes calculated by model with statistical time series for the indexes. The time series are considered similar if they are close as functions of time. The closeness of calculated and statistical data for each macro index is measured by Theil index of inequality. The problem is formulated as an optimal control problem with constraints of general form. A convolution of Theil indexes is maximized. The equations of the model give constraints of the optimal control problem. The unknown parameters of the model are piecewise constant controls of the optimal control problem. The optimal control problem is solved numerically using parallel calculations. Identified model of a Russian economy with structural changes in production function is used for estimation of the Government economic policy.

Game theory

Fri.1.MA 005

New models and solution concepts II

Chair Yin Chen, City University of Hong Kong

Ming Hu, School of Informatics, Kyoto University (with Masao Fukushima)

Existence, uniqueness, and computation of robust Nash equilibrium in a class of multi-leader-follower games

The multi-leader-follower game can be looked on as a generalization of the Nash equilibrium problem (NEP), which contains several leaders and followers. On the other hand, in such real-world problems, uncertainty normally exists and sometimes cannot simply be ignored. To handle mathematical programming problems with uncertainty, the robust optimization (RO) technique assumes that the uncertain data belong to some sets, and the objective function is minimized with respect to the worst case scenario. In this paper, we focus on a class of multi-leader-follower games under uncertainty with some special structure. We particularly assume that the follower's problem only contains equality constraints. By means of the RO technique, we first formulate the game as the robust Nash equilibrium problem, and then the generalized variational inequality (GVI) problem. We then establish some results on the existence and uniqueness of a robust leader-follower Nash equilibrium. We also apply the forward-backward splitting method to solve the GVI formulation of the problem and present some numerical examples to illustrate the behavior of robust Nash equilibria.

Silvia Schwarze, University of Hamburg (with Justo Puerto, Anita Schöbel)

Equilibria in generalized Nash games with applications to games on polyhedra

In generalized Nash equilibrium (GNE) games, a player's strategy set depends on the strategy decisions of the competitors. In particular, we consider games on polyhedra, where the strategy space is represented by a polyhedron. We investigate best-reply improvement paths in games on polyhedra and prove the finiteness of such paths for special cases. In particular, under the assumption of a potential game, we prove existence of equilibria for strictly convex payoffs. In addition, we study multiobjective characterizations of equilibria for general (non-polyhedral) GNE games for the case of monotone payoffs. We show that nondominated points in the decision space are equilibria. Moreover, the equivalence of the sets of equilibria and nondominated points is ensured by establishing an additional restriction on the feasible strategy sets, leading to the new definition of comprehensive sets. As a result, multi-objective optimization techniques carry over to GNE games with monotone payoffs. In addition, we discuss the relation to efficient solutions in the payoff space. Applying those results to games on polyhedra, we yield linear programming formulations for finding equilibria.

Yin Chen, City University of Hong Kong (with Chuangyin Dang)

Computing perfect equilibria of finite n -person games in normal form with an interior-point path-following method

For any given sufficiently small positive number ε , we show that the imposition of a minimum probability ε on each pure strategy in a Nash equilibrium leads to an ε -perfect equilibrium of a finite n -person game in normal form. To compute such an ε -perfect equilibrium, we introduce a homotopy parameter to combine a weighted logarithmic barrier term with each player's payoff function and devise a new game. When the parameter varies from 0 to 1, the new game deforms from a trivial game to the original game. With the help of a perturbation term, it is proved that there exists a smooth interior-point path that starts from an unique Nash equilibrium of the trivial game and leads to an ε -perfect equilibrium of the original game at its limit. A predictor-corrector method is presented to follow the path. As an application of this result, we derive a scheme to compute a perfect equilibrium. Numerical results show that the scheme is effective and efficient.

Game theory

Fri.1.MA 043

Algorithmic game theory

Organizer/Chair Azarakhsh Malekian, Massachusetts Institute of Technology · Invited Session

Brendan Lucier, Microsoft Research New England (with Allan Borodin, Mark Braverman, Joel Oren)

Strategyproof mechanisms for competitive influence in social networks

Motivated by models of competitive influence spread in networks, we study mechanisms for allocating nodes to self-interested agents with negative externalities. For example, a social network provider may wish to allow advertisers to provide special offers to influential individuals. The advertisers benefit in that product adoption may spread through the network, but a competing product may adversely impact the rate of adoption.

We construct a mechanism for distributing advertisement space to two competing players. The mechanism is not specific to any particular model for influence spread; it applies to most previously-studied models. Our mechanism yields a constant factor approximation to the optimal total product influence, and is strategyproof in the sense that advertisers maximize their expected total product diffusion by reporting their advertising demands truthfully. We also discuss extensions of our mechanism to three or more players under additional restrictions that are satisfied by many models studied in the literature.

Nicole Immortica, Northwestern University (with Christina Brandt, Gautam Kamath, Robert Kleinberg)

Social networks and segregation

Social networks form the basic medium of social interaction. The structure of these networks significantly impacts and co-evolves with the behavioral patterns of society. Important societal outcomes – the global reach of an epidemic, the degree of cooperation in an online network, the adoption of new technologies – are dictated by social networks.

In this talk, we explore the impact of networks on segregation. In 1969, economist Thomas Schelling introduced a landmark model of racial segregation in which individuals move out of neighborhoods where their ethnicity constitutes a minority. Simple simulations of Schelling's model suggest that this local behavior can cause global segregation effects. In this talk, we provide a rigorous analysis of Schelling's model on ring networks. Our results show that, in contrast to prior interpretations, the outcome is nearly integrated: the average size of an ethnically-homogenous region is independent of the size of the society and only polynomial in the size of a neighborhood.

Markus Mobius, Microsoft Research New England (with Adam Szeidl, Phan Tuan)

Treasure hunt

We seed a large real-world social network with binary information and analyze subsequent social learning. A unique feature of our field experiment is that we measure both the pre-existing social networks and the actual conversation network. Our experiment allows us to test how rational agents behave when processing information that originates within their social network. We find that information decays quickly with social distance and that agents mainly incorporate information within social distance 2. Conversations through common friends do not increase the weight that a subject places on signals from direct friends but linearly increases the weight on signals from indirect friends. This suggests that agents are able to avoid double-counting information from indirect friends. We propose a simple "streams model" of social learning that is consistent with the evidence from our experiment.

Global optimization

Fri.1.H 0110

Recent advances in nonconvex quadratic programming with random data

Organizer/Chair Jiming Peng, University of Illinois at Urbana-Champaign · Invited Session

Nicolas Gillis, University of Waterloo (with Stephen Vavasis)

Fast and robust recursive algorithm for separable nonnegative matrix factorization

In this paper, we present an extremely fast recursive algorithm for nonnegative matrix factorization under the assumption that the nonnegative data matrix is separable (i.e., there exists a cone spanned by a small subset of the columns containing all columns). We prove that our technique is robust under any small perturbations of the data matrix, and experimentally show that it outperforms, both in terms of accuracy and speed, the state-of-the-art vertex component analysis algorithm of Nascimento and Bioucas-Dias.

Jiming Peng, University of Illinois at Urbana-Champaign

Quadratic optimization with separable objective and a single quadratic and box constraint

We consider the quadratic optimization problem with separable and a single quadratic and box constraint. Such a problem arises from important applications such as asset liquidation and energy system design. The problem is NP-hard.

In this talk, we present an iterative breakpoint search algorithm and establish its convergence. We shall also discuss the probability that the proposed algorithm can locate the global solution to the underlying problem under certain assumptions on the data.

Paul Krokhmal, University of Iowa

Asymptotic properties of random multidimensional assignment problems

We consider a class of discrete optimization problems where the underlying combinatorial structure is based on hypergraph matchings,

which generalize the well-known problems on bipartite graph matchings, such as the Linear and Quadratic Assignment Problems, and are also known as multidimensional assignment problems (MAPs). Properties of large-scale randomized instances of MAPs are studied under assumption that their assignment costs are iid random variables. In particular, we consider linear and quadratic problems with sum and bottleneck objectives. For a broad class of probability distributions, we demonstrate strong convergence properties of optimal values of random MAPs as problem size increases. The analysis allows for identifying a subset of the feasible region containing high-quality solutions. We also investigate the average-case behavior of Linear Sum MAP in the case when the assumption regarding independence of the assignment costs is relaxed, and a correlation structure is present in the array of assignment costs. In particular, we consider the case of LSMAP with decomposable assignment costs.

Global optimization

Fri.1.H 2053

Advances in global optimization IV

Chair Syuuji Yamada, Niigata University

Syuuji Yamada, Niigata University (with Tamaki Tanaka, Tetsuzo Tanino)

Global optimization methods utilizing partial separating hyperplanes for a canonical dc programming problem

In this talk, we consider a canonical dc programming problem (CDC) to minimize a linear function over the difference between a compact convex set and an open bounded convex set. It is known that many global optimization problems can be transformed into (CDC). Hence, for (CDC), many approximation algorithms based on outer approximation methods and branch-and-bound procedures have been proposed. However, since the volume of data necessary for executing such algorithms increases in proportion to the number of iterations, such algorithms are not effective for large scale problems. Hence, to calculate an approximate solution of a large scale (CDC), we propose new iterative solution methods. To avoid the growth of data storage, the proposed methods find an approximate solution of (CDC) by rotating a partial separating hyperplane around a convex set defining the feasible set at each iteration. Moreover, in order to improve the computational efficiency of the proposed methods, we utilize the polar coordinate system.

Implementations & software

Fri.1.H 1058

Open source software for modeling and optimization

Organizer/Chair Theodore Ralphs, Lehigh University · Invited Session

Gus Gassmann, Dalhousie University (with Jun Ma, Kipp Martin)

Optimization services: Connecting algebraic modelling languages to several solvers using a web-aware framework

The common paradigm in mathematical optimization uses a modular approach consisting of an instance generator, e.g., an algebraic modelling language (AML), and a solver. Loosely coupled systems allow the substitution of one solver or AML for another. This is especially attractive when one considers open-source software, such as the suite of solvers that make up the COIN-OR project. However, the communication of solver options is an often overlooked detail. Solver developers often use options specific to their own solvers, and even where two solvers use the same option, syntax and interpretation may differ. This can be cumbersome, especially if the AML and solver reside on different computers. In addition, open-source solvers are often layered on top of other solvers, which adds to the complexity, since solver options may have to be directed at different levels in the solver hierarchy.

Optimization Services is a web-aware framework that provides a common interface between AMLs and a variety of open-source and commercial solvers. This talk explores some of the difficulties encountered in connecting the COIN-OR solver suite to a common AML, and the methods we used to overcome them.

John Forrest, FasterCoin

A bit of CLP (accelerated?)

With the availability of multi-core cpus, graphical processing units and new instructions, it may be time to revisit some ideas on accelerating the simplex method. This talk gives a progress report on a dual simplex code derived from COIN-LP designed to take advantage of new architectures.

Integer & mixed-integer programming

Fri.1.H 2013

Integer programming in data mining

Organizer/Chair Dolores Romero Morales, University of Oxford · Invited Session

Yufeng Liu, University of North Carolina at Chapel Hill

Optimization issues on some margin-based classifiers

Margin-based classifiers have been popular in both machine learning and statistics for classification problems. Such techniques have a wide range of applications, from computer science to engineering to bioinformatics. Among various margin-based classifiers, the Support Vector Machine is a well known example. Despite successes, many margin-based classifiers with unbounded loss functions can be sensitive to outliers. To achieve robustness, nonconvex loss functions can be used instead. However, the corresponding optimization problem involves non convex minimization and can be very challenging to implement. In this talk, I will present some connection of such a nonconvex optimization problem with integer programming and illustrate how to solve the problem via mixed-integer programming. Some alternative more efficient approximation algorithms will be discussed as well.

James Brooks, Virginia Commonwealth University

Counting misclassifications: Robust support vector machines via integer programming

The support vector machine (SVM) for classification is a method for generating rules for assigning data points to categories. The traditional formulation is commonly expressed as a convex quadratic program where the error for an observation is based on its distance to the separating boundary in the feature space. In the interest of enhancing the robustness to outlier observations, we present two formulations that reflect the notion that errors should be counted.

Convex quadratic integer programming formulations are presented for the ramp loss and hard margin loss SVM. We show that the formulations accommodate the kernel trick for SVM while preserving the original geometric interpretation. Solution methods are presented for the formulations, including facets for the convex hull of integer feasible solutions. The consistency of SVM with the alternative loss functions is established. Computational tests indicate that the proposed formulations produce better classification rules on datasets containing unbalanced outliers.

Amaya Nogales Gómez, University of Seville (with Emilio Carrizosa, Dolores Romero Morales)

Matheuristics for Ψ -learning

The ψ -learning classifier is an alternative to the Support Vector Machine classifier, which uses the so-called ramp loss function. The ψ -learning classifier is expected to be more robust, and therefore to have a better performance, when outliers are present.

A Nonlinear Mixed Integer Programming formulation proposed in the literature is analysed. Solving the problem exactly is only possible for data sets of very small size. For datasets of more realistic size, the state-of-the-art is a recent matheuristic, which attempts to solve the MINLP imposing a time limit.

In this talk, a new matheuristic, based on the solution of much simpler Convex Quadratic Problems and Linear Integer Problems, is developed. Computational results are given showing the improvement against the state-of-the-art method.

Integer & mixed-integer programming

Fri.1.H 2032

Matheuristics

Organizer/Chair Marco Boschetti, University of Bologna · Invited Session

José Valério de Carvalho, Universidade do Minho (with Filipe Alvelos, Elsa Silva)

SearchCol algorithms for the level bin packing problem

SearchCol, short for "metaheuristic search by column generation", is an algorithmic framework for approximately solving integer programming / combinatorial optimization problems with a decomposable structure. Each iteration of a SearchCol algorithm is made of three phases: (i) column generation is used to generate solutions to subproblems, (ii) a metaheuristic is used to search the (integer) solution space, and (iii) additional constraints, forcing or forbidding attributes of the incumbent solution, are included in the restricted master problem of column generation guiding the generation of new subproblem's solutions in the following iteration. In this talk, we apply SearchCol algorithms to a bin packing problem where it is intended to minimize the number of used rectangular bins to pack a given set of rectangular items. Additionally, the items must be packed in levels. We present computational

results for different variants of the SearchCol algorithms and compare them with other solution approaches.

Patrick Schittekat, SINTEF ICT (with Tomas Nordlander)

A matheuristic for competence building with the use of nurse re-rostering

The global nursing shortage makes efficient use of these resources vital. Good nurse rosters assist but are often static and span over a long period while the daily personnel situation is more dynamic: nurses get sick, take short notice days off, etc. Commonly, these absences are handled by hiring extra nurses when needed. However, earlier analysis has shown that nurse rotation in combination with hiring is a much more efficient solution. Moreover, re-rostering gets easier if the hospital possesses the best mix of experience level and special skills. In other words, a more suitable competence profile makes re-rostering more beneficial. Nurse rotation (work regularly in another department) builds up competence, which allows for a more robust competence profile – departments become better suited to handle future personnel absences. We present a matheuristic that optimizes the competence profile under the assumption that nurse rotation is allowed and/or the hospital can buy in competence. Our preliminary experiments on small instances show how a more robust competence profile is much more efficient up to 40 %.

Marco Boschetti, University of Bologna (with Turricchia Elisa, Golfarelli Matteo, Rizzi Stefano, Maniezzo Vittorio)

A Lagrangian heuristic for the sprint planning in agile methods

Agile methods have been adopted by an increasing number of companies to make software development faster and nimbler. Most methods divide a project into sprints (iterations), and include a sprint planning phase that is critical to ensure the project success. Several factors impact on the optimality of a sprint plan, e.g., the estimated complexity, business value, and affinity of the user stories (functionalities) included in each sprint, which makes the planning problem difficult.

We present an approach for the sprint planning in agile methods based on a MIP model. Given the estimates made by the project team and a set of development constraints, the optimal solution is a sprint plan that maximizes the business value perceived by users.

Solving to optimality the model by a MIP solver (e.g., IBM Ilog Cplex) takes time and for some instances even to find a feasible solution requires too large computing times for an operational use. For this reason we propose a Lagrangian heuristic based on a relaxation of the proposed model and some greedy algorithms. Computational results on both real and synthetic projects show the effectiveness of the proposed approach.

Integer & mixed-integer programming

Fri.1.H.2033

Integer programming approaches to job scheduling

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Valentina Cacchiani, University of Bologna (with Alberto Caprara, Paolo Toth)

Fixed job scheduling with resource constraints

We study the following general scheduling problem: a set of fixed jobs having start time, end time and weight must be scheduled on a set of machines having a capacity, a cost and capable of executing at most one job at a time. Each job must be executed by a set of machines such that their overall capacity satisfies the job weight. In addition, a setup time must be respected between the execution of two jobs on the same machine, that depends on the two jobs. The goal is to determine the minimum cost schedule. We also study some variants of the problem, one of them having application in Train Unit Assignment. All the considered scheduling problems are NP-hard. We provide a heuristic algorithm based on the optimal solution of the restricted problem associated with a peak period, i.e., with a subset of simultaneous jobs that must be executed on distinct machines. The heuristic algorithm is tested on real-world instances of the Train Unit Assignment and on realistic instances for all the variants and the general case. The results obtained are compared with results in the literature, showing the effectiveness of the new algorithm in providing good solutions in short computing time.

Riley Clement, University of Newcastle (with Natasha Boland, Hamish Waterer)

A big-bucket time-indexed formulation for nonpreemptive single machine scheduling problems

Nonpreemptive single machine scheduling problems require a set of jobs to be scheduled on a single machine such that each job is processed exactly once without interruption and the machine processes at most one job at a time. The classical time-indexed (TI) formulation of this problem discretizes a planning horizon into periods of unit length. We present a big-bucket time-indexed (TIBB) formulation in which the length of each period is no larger than the processing time of the shortest job. The two models are equivalent in the case that this job has unit

processing time. When the minimum processing time is larger than the greatest common divisor of the problem input data the TIBB model has fewer periods than the TI model. We show how to adapt facet-defining inequalities for the TI model to the TIBB model and describe conditions under which they are facet-defining. Computational experiments compare the performance of the TIBB model to the TI model for both weighted completion time and weighted tardiness instances described in the literature.

Hamish Waterer, University of Newcastle (with Natasha Boland, Thomas Kalinowski, Zheng Lanbo)

Maintenance scheduling in critical infrastructure networks

Many infrastructure systems critical to modern life take the form of a flow in a network over time. For example, utilities such as water, sewerage and electricity all flow over networks. Products are manufactured and transported via supply chain networks. Such networks need regular, planned maintenance in order to continue to function. A maintenance job causes arc outages for its duration, potentially reducing the capacity of the network for that period. The coordinated timing of maintenance jobs can have a major impact on the network capacity lost to maintenance. This issue drives an annual maintenance scheduling process at the Hunter Valley Coal Chain, which supplies the world's largest coal export operation at the port of Newcastle, Australia, and has motivated this work. Here we describe the background to the problem, how we model it, and our solution approach. The results on instances derived from real-world data will be presented.

Life sciences & healthcare

Fri.1.MA.376

Model discrimination and experimental design

Chair Alexandra Herzog, Philipps-Universität Marburg

Max Nattermann, Philipps-Universität Marburg (with Ekaterina Kostina)

A quadratic approximation of confidence regions

Dealing with the task of identifying unknown quantities from a set of erroneous data, the performance of a sensitivity analysis is inevitable. Without the determination of the statistical accuracy, we are not able to make any quality statements about the estimate. Consequently the result is almost meaningless. Commonly one applies linearization techniques to determine the statistical accuracy of the solution. But particularly in highly nonlinear cases this may cause problems and linear confidence regions may not be adequate. In this talk, we are going to present and analyze a confidence region based on a quadratic approximation. Furthermore, we demonstrate our results using applications from biology. Furthermore, we discuss the impact of the new results to optimum experimental design.

Tanja Binder, Philipps-Universität Marburg (with Ekaterina Kostina)

Numerical optimization methods for significance analysis of parameters and subsets of metabolic networks

We have developed an efficient numerical method, based on sensitivity analysis for parametric optimization problems, that can be used to identify the most important signaling pathways and the key parameters and variables in a mathematical model that is given by a system of ordinary differential equations. In the context of metabolic pathways, our approach can be used to guide experimental biologists in their choice which proteins they should measure. Mathematically, the problem results in the question how much improvement in terms of the cost function can be achieved by adding additional terms to the underlying dynamical model, i.e., whether these are to be included or not. The cost function describes the quality of the model response in comparison to process observations. After a parameter estimation for the simplest model, we can decide fast whether additional terms should be included in the model without having to re-optimize the enlarged models. We show the capability, reliability, and efficiency of our approach using complex problems from systems biology.

Alexandra Herzog, Philipps-Universität Marburg (with Regina Gente, Ekaterina Kostina)

Discrimination of competitive model candidates for reversals in bacterium *Myxococcus xanthus*

Reversals in the gram-negative bacterium *M. xanthus* are still poorly understood. In general the spatial relocalisation of motility proteins is assumed to determine the dynamic orientation of the cell polarity axis and hence cell reversals. The difficulty is that experimental data from fluorescence microscopy on the simultaneous localisation of the involved proteins is both rare and of a more qualitative nature. Protein dynamics are recorded individually. Correlated data is available as qualitative observations only. Simulations of the dynamics of all involved proteins are typically the only means to study the processes under investigation.

In this talk we discuss numerical optimization methods for discrimination between available deterministic and semi-stochastic models for

protein localisation of the supposed predominant proteins MglA and MglB. Qualitative reconstruction of the observed characteristic dynamics and transport times for available proteins is used as discrimination criteria. The extremely sparse experimental data sets mark a special challenge of this application. Current results and limitations of this approach are discussed.

Logistics, traffic, and transportation

Fri.1.H 0106

Optimizing robot welding cells

Organizers/Chairs Jörg Rambau, Universität Bayreuth; Martin Skutella, TU Berlin · Invited Session

Jürgen Pannek, University of the Federal Armed Forces Munich

Collision avoidance via distributed feedback design

We consider a distributed non cooperative control setting in which systems are interconnected via state constraints. Each of these systems is governed by an agent which is responsible for exchanging information with its neighbours and computing a feedback law using a nonlinear model predictive controller to avoid collisions. For this setting we present an algorithm which generates a parallelizable hierarchy among the systems. Moreover, we show both feasibility and stability of the closed loop using only abstract properties of this algorithm. To this end, we utilize a trajectory based stability result which we extend to the distributed setting.

Cornelius Schwarz, University of Bayreuth (with Joachim Schauer)

The laser sharing problem with fixed tours

In the Laser Sharing Problem (LSP) a set of industrial arc welding robots has to perform a series of welding seams. For this task they need to be connected to a laser source supplying them with the necessary energy. In principle, a laser source can serve up to six robots but only one at a time. The task of the LSP is to find an assignment of a given set of laser sources to robots and collision-free robot tours so that welding seams performed using the same laser source do not overlap in time and the overall makespan is minimal.

Prescribing the robot tours we obtain a pure scheduling problem referred to as LSP-T. We will show that LSP-T can be seen as an extension of the famous job-shop problem. Then we extend the geometric approach of Akers for the two job-shop problem to LSP-T leading to a polynomial algorithm for the two robot case.

Since the job-shop problem is a special case of LSP-T the three robot case is already NP-hard. We will propose a pseudo-polynomial algorithm for it based on transversal graphs and show how to derive a FPTAS. By this we fully settle the complexity of LSP-T with a constant number of robots.

Wolfgang Welz, TU Berlin

Conflict-free job assignment and tour planing of welding robots

In welding cells a certain number of robots performs spot welding tasks on a workpiece. The tours of the welding robots are planned in such a way that all weld points on the component are visited and processed within the cycle time of the production line. During this operation, the robot arms must not collide with each other and safety clearances have to be kept. On the basis of these specifications, we show an approach how methods of discrete optimization can be used in combination with nonlinear optimization to find solutions for the stated problem. Intermediate results from the combinatorial collision-aware dispatching problem can be used to identify promising tours. Calculating the exact trajectories for those tours only keeps the computational expensive calculations to a minimum. The discrete part leads to a Vehicle Routing based problem with additional scheduling and timing aspects induced by the necessary collision avoidance. This problem can be solved as an integer linear program by column generation techniques. In this context, we adapt a version of the shortest path problem with time windows so that it can be used to solve the pricing problem with collision avoidance.

Logistics, traffic, and transportation

Fri.1.MA 042

Disruption management

Chair Stephen Maher, University of New South Wales

Stephen Maher, University of New South Wales

Integrated airline recovery problem on a minimal disruption neighbourhood

The airline recovery problem is a very complex process involving a number of stages in the operations control centre. In an effort to reduce the size of the recovery problem a disruption neighbourhood is

defined, generally in a preprocessing step, to determine the disruptable resources. While this reduces the problem size and improves tractability, there is a tradeoff with the final solution quality. We propose a model that aims to solve the integrated crew and aircraft recovery problem on a minimal disruption neighbourhood. As a result we attempt to provide a solution to the operations controller that requires the least amount of disruptable aircraft and crew at a minimal cost in the recovery process.

Kazuhiro Kobayashi, National Maritime Research Institute, Tokyo

Alternative objective functions in ship scheduling for managing supply chain disruption risk

To gain cost advantages, many shipping companies generate ship schedules which minimize transportation cost. There are effective in a stable environment. However, there are vulnerable to supply chain disruptions caused by uncertain economic crisis, natural and man-made disasters. Effectively responding to such disruption risk is of crucial importance for continuing business activities. For this purpose, it is necessary to generate ship schedules which result in quick and sufficient distribution of supplies, with a focus on equitable service to all locations concerning the disruptions. However, quantifying such goals can be challenging. In this work, we introduce alternate objectives in ship scheduling problem which are different from the one minimizing transportation costs. Moreover, we show how these objective functions affect the ship schedules.

Lucian Ionescu, Department Information Systems (with Natalia Kliewer)

Stochastic optimization models for airline resource schedules under disruptions

In this talk we compare two stochastic models considering the robustness and cost-efficiency of airline resource schedules. The first model deals with the delay absorbing capacity of schedules, the second with the recoverability during operations. These two aspects can be called stability and flexibility. Both models are solved by a branch-and-price&cut-algorithm. The resulting schedules are evaluated by an event-based simulation including a delay propagation model and a rule-based recovery approach. This enables us to identify possible mutual impacts, e.g., if stable schedules still offer the same degree of swap opportunities for operational recovery and vice versa. The presented analysis is a pre-step to an integrated stochastic approach for considering both stability and flexibility aspects at the same time during scheduling.

Mixed-integer nonlinear programming

Fri.1.MA 041

Applications of MINLP I

Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen · Invited Session

Claudia Stangl, University of Duisburg-Essen (with Ralf Gollmer, Rüdiger Schultz)

Feasibility testing for transportation orders in real-life gas networks

Checking the feasibility of transportation requests belongs to the key tasks in gas pipeline operation. In its most basic form, the problem is to decide whether a certain quantity of gas can be sent through the network from prescribed entries to prescribed exit points. In the stationary case, the physics of gas flow together with technological and commercial side conditions lead to a pretty big (nonlinear, mixed-integer, finite dimensional) inequality system. We present elimination and approximation techniques so that the remaining system gets within the reach of standard NLP-solvers.

Francois Margot, Carnegie Mellon University (with Iacopo Gentilini, Kenji Shimada)

The traveling salesman problem with neighborhoods: MINLP solution

The traveling salesman problem with neighborhoods extends the traveling salesman problem to the case where each vertex of the tour is allowed to move in a given region. This NP-hard optimization problem has recently received increasing attention in several technical fields such as robotics, unmanned aerial vehicles, or utility management. We formulate the problem as a nonconvex Mixed-Integer NonLinear Program (MINLP) having the property that fixing all the integer variables to any integer values yields a convex nonlinear program. This property is used to modify the global MINLP optimizer Couenne, improving by orders of magnitude its performance and allowing the exact solution of instances large enough to be useful in applications. Computational results are presented where neighborhoods are either polyhedra or ellipsoids in \mathbb{R}^2 or \mathbb{R}^3 and with the Euclidean norm as distance metric.

Jakob Schelbert, FAU Erlangen-Nürnberg, Discrete Optimization (with Sonja Mars, Lars Schewe)

How to route a pipe – Discrete approaches for physically correct routing

We consider a real-world problem of routing a pipe through a power plant. This is done with a MISOCP model which is solved to global optimality. The problem combines discrete aspects and non-linear constraints that model the physics of the pipe. Conventional truss topology

optimization methods are not directly applicable. This follows from the discrete constraints that force the pipe to form a path or even a Steiner tree. The underlying physics of the pipe can be expressed via a SOCP formulation. Additional combinatorial constraints, that are used to force the pipe to a certain design, call for the use of binary variables which renders the problem a MISOCP. In our real-world application a rough outline of the admissible region, a start and end point are given. In addition to the self-weight of the pipe we are also asked to place hangers that provide support for the pipe. Furthermore we use Timoshenko beams for our pipe to consider a more accurate physical model. We give some numerical results and show how to speed up the solving process by discrete optimization techniques to obtain global optimality.

Multi-objective optimization

Fri.1.H 1029

Bilevel optimization and risk management

Chair Frank Heyde, University of Graz

Johannes Jahn, University of Erlangen-Nuremberg (with Dietmar Fey, Steffen Limmer)

GPU implementation of a multiobjective search algorithm

In this talk we discuss the use of graphics processing units (GPU) in multiobjective optimization. For a known multiobjective search algorithm with subdivision technique we describe a possible implementation and we present numerical results for test problems together with the achieved speed ups.

Joerg Fliege, University of Southampton (with Konstantinos Karpas, Huifu Xu)

Reformulations of multiobjective bilevel problems

We present new approaches for multiobjective bilevel optimization, derived from an optimality condition for the lower level problem that leads naturally to a nonsmooth equality constraint. The nonsmoothness of the new constraint stems from its derivation as an optimal value function of a particular direction search problem. Preliminary numerical results on bilevel problems occurring in electricity markets show the efficacy of the approach. Further, we consider possible extensions to the multilevel case.

Frank Heyde, University of Graz (with Andreas Hamel, Birgit Rudloff, Benjamin Weißing)

Set-valued average value at risk

Since the seminal paper of Artzner, Delbaen, Eber and Heath (1999), coherent measures of risk are considered to be an important tool for risk management. The most prominent example of a coherent risk measure is "Average (Conditional) Value at Risk (AVaR)". In the presence of transaction costs it turned out that set-valued risk measures are in general better suited to cope with multiple markets than real-valued functions. A general theory of set valued convex risk measures was developed by Hamel, Heyde (2010) and Hamel, Heyde, Rudloff (2011). Within this framework we will present a set-valued version of the AVaR. A primal and dual description will be given which extend the real-valued case to the set-valued framework. The equivalence of the two descriptions is shown using a set-valued Fenchel-Rockafellar duality theorem developed by Hamel (2011).

Nonlinear programming

Fri.1.H 0107

Optimality conditions and constraint qualifications

Organizer/Chair José Mario Martínez, University of Campinas · Invited Session

Maria Maciel, Universidad Nacional del Sur (with Gabriel Carrizo, Pablo Lotito)

A trust region algorithm for the nonconvex unconstrained vector optimization problem

A trust-region-based algorithm for the non convex unconstrained vector optimization problem is considered. It is a generalization of the algorithms proposed by Fliege, Graña Drumond and Svaiter (2009) for the convex problem. Similarly to the scalar case, at each iteration, a trust region subproblem is solved and the step is evaluated. The notions of decrease condition and of predicted reduction are adapted to the vector case. A rule to update the trust region radius is introduced. Under differentiability assumptions, the algorithm converges to a Pareto point satisfying a necessary condition and in the convex case to a Pareto point satisfying necessary and sufficient conditions like the procedure proposed by the cited authors.

Paulo Silva, University of São Paulo (with Roberto Andreani, Gabriel Haeser, Maria Schuverdt)

Constant positive generators: A new weak constraint qualification with algorithmic applications

This talk introduces a generalization of the constant rank of the subspace component constraint qualification called the constant positive generator condition (CPG). This new constraint qualification is much

weaker. For example, it can hold even in the absence of an error bound for the constraints and it can hold at a feasible point x while failing arbitrarily close to x .

In spite of its generality, it is possible to show that CPG is enough to ensure that almost-KKT points are actually KKT. Hence, this new condition can be used as a very mild assumption to assert the convergence of many algorithms to first order stationary points. As examples, we present extensions of convergence results for algorithms belonging to different classes of nonlinear optimization methods: augmented Lagrangians, inexact restoration, SQP, and interior point methods.

Santosh Srivastav, Jaypee University of Engineering and Technology

Fritz John duality in the presence of equality and inequality constraints

A dual for a nonlinear programming problem in the presence of equality and inequality constraints is formulated which uses Fritz John optimality conditions instead of the Karush-Kuhn-Tucker optimality conditions and thus does not require a constraint qualifications. Various duality results, namely, weak, strong, strict converse and converse duality theorems are established under suitable generalized convexity assumptions.

Nonlinear programming

Fri.1.H 0112

Complexity issues in optimization

Chair Jianming Shi, Muroran Institute of Technology (MuIT)

Stefan König, Technische Universität München (with Christian Knauer, Daniel Werner)

Norm maximization is $W[1]$ -hard

The problem of maximizing the p th power of a p -norm over a half-space presented polytope in \mathbb{R}^d is a convex maximization problem which plays a fundamental role in computational convexity. It has been known since 1986 that this problem is NP-hard for all values $p \in \mathbb{N}$, if the dimension d of the ambient space is considered as part of the input.

In recent years, the theory of parametrized complexity has become a helpful tool in analysing how the hardness of problems depends on specific parameters of the input. In this talk, we will briefly discuss the prerequisites from parametrized complexity and then investigate the complexity of norm maximization with the natural choice of d as parameter.

More precisely, we show that, for $p = 1$, the problem is *fixed parameter tractable* (i.e., it can be considered as computationally feasible if only the dimension d is small) but that, for all $p \in \mathbb{N} \setminus \{1\}$, norm maximization is $W[1]$ -hard. The presented reduction also yields that, under standard complexity theoretic assumptions, there is no algorithm with running time $n^{o(d)}$ that answers the problem correctly.

Claudio Santiago, Lawrence Livermore National Laboratory (with Maria Helena Jardim, Nelson Maculan)

An efficient algorithm for the projection of a point on the intersection of two hyperplanes and a box in \mathbb{R}^n

In this work, we present an efficient strongly polynomial algorithm for the projection of a point on the intersection of two hyperplanes and a box in \mathbb{R}^n . Interior point methods are the most efficient algorithm in the literature to solve this problem. While efficient in practice, the complexity of interior point methods is bounded by a polynomial in the dimension of the problem and in the accuracy of the solution. In addition, their efficiency is highly dependent on a series of parameters depending on the specific method chosen (especially for nonlinear problems), such as step size, barrier parameter, accuracy, among others. We propose a new method based on the KKT optimality conditions. In this method, we write the problem as a function of the lagrangian multipliers of the hyperplanes and seek to find the pair of multipliers that corresponds to the optimal solution. We prove that the algorithm has complexity $O(n^2 \log n)$.

Jianming Shi, Muroran Institute of Technology (MuIT) (with Shi Jianming)

A computational geometric approach for solving linear programming: Toward strong polynomial

The complexity of linear programming (LP) is still open because we don't know whether there exists a strongly polynomial algorithm for solving a Linear program. This talk is an effort toward this long-standing open problem.

Unlike previous approaches, the algorithm proposed in talk does not require the information of the vertices of the feasible region. Under the assumption that an interior point in the feasible region is available, we reformulate a LP as a computational geometric problem with a convex hull of the data points (vectors).

We will report the experiments results comparing the new approach and the existing methods, like the interior point method, Simplex method.

Nonsmooth optimization

Fri.1.H 1012

Topics in nonsmooth nonconvex optimization

Chair Jean-Louis Goffin, McGill University

Wilhelm Freire, Federal University of Juiz de Fora (with Regina Burachik, C. Yalcin Kaya)

Interior epigraph directions method for nonsmooth and nonconvex optimization via generalized augmented Lagrangian duality

We propose a new method, called Interior Epigraph Directions Method (IED), for constrained nonsmooth and nonconvex optimization which uses a generalized augmented Lagrangian duality scheme. The IED method takes advantage of the special structure of the epigraph of the dual function. We prove that all the accumulation points of the primal sequence generated by IED are solutions of the original problem. We carry out numerical experiments by using test problems from the literature. In particular, we study several instances of the Kissing Number Problem. Our experiments show that the quality of the solutions obtained by IED is comparable with those obtained by other solvers.

Izhar Ahmad, King Fahd University of Petroleum and Minerals

Optimality conditions in nondifferentiable multiobjective fractional programming

A nondifferentiable multiobjective fractional programming problem is considered. Fritz John and Kuhn-Tucker type necessary and sufficient conditions are derived for a weak efficient solution. Kuhn-Tucker type necessary conditions are shown to be sufficient for a properly efficient solution. This result gives conditions under which an efficient solution is properly efficient. An example is discussed to illustrate this result.

Jean-Louis Goffin, McGill University (with Ahad Dehghani, Dominique Orban)

Solving unconstrained nonconvex programs with ACCPM

We suggest the use of ACCPM and proximal ACCPM, well known techniques for convex programming problems, in a sequential convex programming method based on ACCPM and convexification techniques to tackle unconstrained problems with a non-convex objective function, by adding a proximal term to the objective. We also report a comparison of our method with some existing algorithms: the steepest descent method and nonlinear conjugate gradient algorithms.

We use a sequence of convex functions and show that the global minimizers of these convex functions converge to a local minimizer of the original nonconvex objective function f . These convex functions are minimized by using ACCPM-prox, a code developed by J. P. Vial.

We use the set problem CUTER and tested two version of our algorithm, ACCPM_AdaotTol and ACCPM_FixTol on 158 problems of this set. The number of variables on these 158 problems varies from 2 to 20,000. This software presents ACCPM_AdaptTol as the best solver on more than 22% of the problems and it can solve approximately 85% of the problems.

Optimization in energy systems

Fri.1.MA 549

Power flow modelling and mechanism design

Chair Deepak Bagchi, Infosys Ltd.

Stephan Lemkens, RWTH Aachen University (with Arie Koster)

Structural properties of power grid design

The problem of designing a cost minimal power grid is often formulated as a mixed integer linear program using the well known DC power flow linearization. We consider its projection on the integral space, as every feasible integral point can be considered as a possible power grid design. We define the DC power grid design polytope as the convex hull of these integral points. At first, we will consider the case in which the power flow on each line is not restricted by any means. We will show, that in this setting the convex hull is described by the connected subgraph polytope of the topology graph. In addition, we will discuss the structural properties under the influence of bounded power flows, as every real world scenario requires bounded flows. Further, we will study the effects on the convex hull under the assumption of a metric topology. Finally, we will discuss the impact on the stated results in the case where we use AC linear power flows instead of the DC power flow linearization.

Waqquas Bukhsh, University of Edinburgh (with Andreas Grothey, Ken McKinnon, Paul Trodden)

Local solutions of optimal power flow problem

Optimal power flow (OPF) is a well studied optimization problem in electricity industry. Over the last two decades it has become a standard tool for planning, real time operations and market auctions.

OPF is nonlinear optimization problem and the existence of locally optimal solutions has been a question of interest for decades. Often it is conjectured that OPF feasible region is convex. In this talk, we present

examples of local solutions of OPF on a range of power systems networks. We also show that a recent reformulation of OPF as SDP problem sometimes fails to recover feasible solutions of OPF.

Deepak Bagchi, Infosys Ltd. (with Shantanu Biswas)

Optimal combinatorial auction for smart grids with renewable energy resources

We present an optimal combinatorial auction mechanism for the virtual power plant (VPP) formation problem in a smart grid with renewable energy sources. The VPP planner can source electricity from various suppliers generating electricity from renewable energy sources. The planner has to solve the VPP formation problem to determine which VPP to form at any given point of time. We take into consideration the uncertainty in availability of renewable energy sources due to changing weather patterns.

To the best of our knowledge this is the first attempt at developing an optimal mechanism for the VPP formation problem. We have incorporated the uncertainty in availability of energy from renewable resources in the auction formulation to minimize the associated risks. We have stated and proved the necessary and sufficient conditions for Myerson optimal auction for VPP formation problem in the presence of single minded suppliers.

Optimization in energy systems

Fri.1.MA 550

Optimal control

Chair Jean-Christophe Alais, ENPC, Université Paris-Est

Jean-Christophe Alais, ENPC, Université Paris-Est

On managing the hydroelectric production of a dam by means of the viability theory

To manage a dam hydroelectric production, we have to cope with economic and tourist stakes which are mutually conflicting since they compete for the use of a common resource: the reservoir water. We first consider the expected gain stemming from the production as the criterion to maximize and the tourist stake is modelled as to ensure a storage level s during the tourist season, at a given probability level. This leads to a chance-constrained optimal control problem we solve by the Uzawa algorithm. Albeit the optimal strategy meets the a priori-specified requirements, the deviation of the reached gain from its expected value is significant. Therefore, handling the dam management this way may not be satisfactory when the dispersion of the reached gains is of interest. In another way, a viability approach to the problem may be to do our best to respect the storage level s during the tourist season while guaranteeing ourselves a reached gain g . Thus, we symmetrize the stakes by maximizing $\mathbb{P}(gain \geq g \text{ and } storage \geq s)$. We design and then solve the problem, which is the occasion to study the maximization of a multiplicative gain by dynamic programming.

PDE-constrained opt. & multi-level/multi-grid meth.

Fri.1.H 0111

Optimal control of PDEs with advection terms

Chair Mohamed Al-Lawatia, Sultan Qaboos University

Anis Younes, Research Unit: Optimization, Modeling and Decision Support (with Mohamed Bouchiba, Abdenaceur Jarray)

The Navier-Stokes problem in velocity-pressure formulation: Convergence and optimal control

We study the nonlinear Navier-Stokes problem in velocity-pressure formulation. We construct a sequence of a Newton-linearized problems and we show that the sequence of weak solutions converges towards the solution of the nonlinear one in a quadratic way. A control problem on the homogeneous problem is considered.

Sebastian Pfaff, Technische Universität Darmstadt (with Stefan Ulbrich)

Optimal boundary control for nonlinear hyperbolic conservation laws with source terms

Hyperbolic conservation laws arise in many different applications such as traffic modelling or fluid mechanics. The difficulty in the optimal control of hyperbolic conservation laws stems from the occurrence of moving discontinuities (shocks) in the entropy solution. This leads to the fact that the control-to-state mapping is not differentiable in the usual sense.

In this talk we consider the optimal control of a scalar balance law on a bounded spatial domain with controls in source term, initial data and the boundary condition. We show that the state depends shift-differentially on the control by extending previous results for the control

of Cauchy problems. Furthermore we present an adjoint-based gradient representation for cost functionals. The adjoint equation is a linear transport equation with discontinuous coefficients on a bounded domain which requires a proper extension of the notion of a reversible solution. The presented results form the basis for the consideration of optimal control problems for switched networks of nonlinear conservation laws.

Mohamed Al-Lawatia, Sultan Qaboos University

A rational characteristic method for advection diffusion equations

We present a characteristic method for the solution of the two-dimensional advection diffusion equations which uses Wachspress-type rational basis functions over polygonal discretizations of the spatial domain within the framework of the Eulerian-Lagrangian localized adjoint methods (ELLAM). The derived scheme maintains the advantages of previous ELLAM schemes and generates accurate numerical solutions even when large time steps are used in the simulation. Numerical experiments are presented to illustrate the performance of the method and to investigate its convergence numerically.

PDE-constrained opt. & multi-level/multi-grid meth.

Fri.1.MA 415

Reduced order model based optimization

Chair Jane Ghiglieri, Technische Universität Darmstadt

Andreas Schmidt, IWR, Universität Heidelberg (with Hans-Georg Bock, Stefan Körkel)

POD reduced-order modeling in the context of direct-approach optimization

To solve optimization problems that involve PDE constraints in general two approaches are distinguished, namely the direct and the indirect approach where we either 'first discretize – then optimize' or 'first optimize – then discretize'. If Proper Orthogonal Decomposition (POD) is used to reduce the size of the optimization problem in most of the applications this takes place in the indirect setting.

We will consider the use of POD in a direct-approach setting together with time-dependent PDEs. We can see that a naive application of POD will result in a reduced-order model that lacks the essential property to reflect derivative information of the original high-fidelity model. A remedy to overcome this is the inclusion of necessary derivative information obtained from the high-fidelity model. We will see that the resulting 'enriched' reduced-order model has very beneficial properties. More specifically we obtain accurate approximations to the original problem of either forward derivatives or adjoint derivatives. Furthermore the derivatives will always be consistent even for changing parameter configurations.

Jane Ghiglieri, Technische Universität Darmstadt (with Stefan Ulbrich)

Optimal flow control based on POD and MPC for the cancellation of Tollmien-Schlichting waves by plasma actuators

The occurrence of a transition in a flat plate boundary layer is characterized by the formation of growing disturbances inside the boundary layer, the Tollmien-Schlichting waves. Successful damping of these waves can delay transition for a significant distance downstream, lowering the skin friction drag of the body.

We consider plasma actuators which induce a body force for active flow control. By optimal control of the plasma actuator parameters it is possible to reduce or even cancel the Tollmien-Schlichting waves and delay the turbulence transition. We present a Model predictive control (MPC) approach for the cancellation of Tollmien-Schlichting waves in the boundary layer of a flat plate. We use proper orthogonal decomposition (POD) for the low-order description of the flow model and the optimization of the control parameters is performed within the reduced system. Furthermore, we will show methods for improving the reduced model whose quality is verified in comparison to the results of a finite element based simulation for the considered problem. Finally, we present our cancellation results with this MPC approach in a numerical simulation.

Daniela Koller, Technische Universität Darmstadt (with Stefan Ulbrich)

Optimal control of hydroforming processes based on POD

The sheet metal hydroforming process is a complex forming process, which involves contact, friction and plasticity to manufacture curved sheet metals with bifurcated cross section. These sheet metal products are examined within the Collaborative Research Centre (CRC) 666. Mathematically, the sheet metal hydroforming process leads to an evolution quasi-variational inequality. We seek for optimal controls of the process relevant control variables, e.g., the time dependent blank holder force and the fluid pressure. Since the resulting VI-constrained optimization problem is very complex and computationally intensive, we apply model reduction techniques. We use Proper Orthogonal Decomposition (POD) to obtain a low-order model of the hydroforming process. Based on a Galerkin approximation and a semismooth reformulation we

will discuss the derivation of a reduced model for the evolution variational inequality.

Numerical results of a simplified engineering application for the optimal control of hydroforming processes will be presented.

Robust optimization

Fri.1.MA 004

A robust optimization approach to stochastic analysis

Organizers/Chairs Nataly Youssef, MIT; Chaithanya Bandi, Operations Research Center, MIT · Invited Session

Chaithanya Bandi, Operations Research Center, MIT (with Dimitris Bertsimas)

Optimal design for multi-item auctions: A robust optimization approach

We revisit the auction design problem for multi-item auctions with budget constrained buyers by introducing a robust optimization approach to model (a) concepts such as incentive compatibility and individual rationality that are naturally expressed in the language of robust optimization and (b) the auctioneer's beliefs on the buyers' valuations of the items. Rather than using probability distributions (the classical probabilistic approach) or an adversarial model to model valuations, we introduce an uncertainty set based model for these valuations. We construct these uncertainty sets to incorporate historical information available to the auctioneer in a way that is consistent with limit theorems of probability theory or knowledge of the probability distribution. In this setting, we formulate the auction design problem as a robust optimization problem and provide a characterization of the optimal solution as an auction with reservation prices, thus extending the work of Myerson (1981) from single item without budget constraints, to multiple items with budgets, potentially correlated valuations and uncertain budgets.

Nataly Youssef, MIT (with Chaithanya Bandi, Dimitris Bertsimas)

Robust queueing theory

We propose an approach for studying queueing systems by employing robust optimization as opposed to stochastic analysis. While traditional queueing theory relies on Kolmogorov's axioms and models arrivals and services as renewal processes, we use the limiting laws of probability as the axioms of our methodology and model the queueing primitives by uncertainty sets. We begin by analyzing the performance of single-class multi-server queues and obtain closed form expressions for the waiting times with heavy-tailed arrival and service processes; expressions that are not available under traditional queueing theory. We develop an exact calculus for analyzing a network of queues based on the following key principle: (a) the departure, (b) the superposition, and (c) the thinning of arrival processes have the same uncertainty set representation as the original arrival processes. We also derive closed form expressions for the transient behavior of single class queues and feed-forward networks. We show that our approach (a) yields accurate results in comparison to simulations for large scale queueing networks, and (b) is to a large extent insensitive to network size and traffic intensity.

Dimitris Bertsimas, MIT (with Chaithanya Bandi)

Network information theory via robust optimization

We present a robust optimization framework to solve the central problem of network information theory of characterizing the capacity region and constructing matching optimal codes for multi-user channels with interference. We first formulate the single user Gaussian channel as a semidefinite optimization problem with rank one constraints and recover the known capacity region (Shannon-1948) and construct a matching optimal code. We then characterize the capacity regions of the multi-user Gaussian interference channel, the multicast and the multi-access Gaussian channels and construct matching optimal codes by solving semidefinite optimization problems with rank one constraints. We report numerical results that show that our proposed approach is numerically tractable for code-book sizes of up to 100,000 codewords. We further examine how the probability description of noise affects the nature of the corresponding optimization problem and show that for the case of exponential channels the optimization problem becomes a binary, mixed linear optimization problem that can be solved by commercial solvers.

Sparse optimization & compressed sensing

Fri.1.H 1028

Greedy algorithms for sparse optimization

Organizer/Chair Shai Shalev-Shwartz, The Hebrew University · Invited Session

Pradeep Ravikumar, University of Texas at Austin (with Inderjit Dhillon, Ambuj Tewari)

Nearest neighbor based greedy coordinate descent

Increasingly, optimization problems in machine learning, especially those arising from high-dimensional statistical estimation, have a large

number of variables. Modern statistical estimators developed over the past decade have statistical or sample complexity that depends only weakly on the number of parameters when there is some structure to the problem, such as sparsity. A central question is whether similar advances can be made in their computational complexity as well. In this talk, we propose strategies that indicate that such advances can indeed be made. In particular, we investigate the greedy coordinate descent algorithm, and note that performing the greedy step efficiently weakens the costly dependence on the problem size provided the solution is sparse. We then propose a suite of methods that perform these greedy steps efficiently by a reduction to nearest neighbor search. We also develop a practical implementation of our algorithm that combines greedy coordinate descent with locality sensitive hashing, using which we are not only able to significantly speed up the vanilla greedy method, but also outperform cyclic descent when the problem size becomes large.

Prateek Jain, Microsoft Research Lab (with Inderjit Dhillon, Ambuj Tewari)

Orthogonal matching pursuit with replacement

In this paper, we consider the problem of compressed sensing where the goal is to recover almost all the sparse vectors using a small number of fixed linear measurements. For this problem, we propose a novel partial hard-thresholding operator that leads to a general family of iterative algorithms. While one extreme of the family yields well known hard thresholding algorithms like ITI (Iterative Thresholding with Inversion) and HTP (Hard Thresholding Pursuit), the other end of the spectrum leads to a novel algorithm that we call Orthogonal Matching Pursuit with Replacement (OMPR). OMPR, like the classic greedy algorithm OMP, adds exactly one coordinate to the support at each iteration, based on the correlation with the current residual. However, unlike OMP, OMPR also removes one coordinate from the support. This simple change allows us to prove that OMPR has the best known guarantees for sparse recovery in terms of the Restricted Isometry Property (a condition on the measurement matrix). Our proof techniques are novel and flexible enough to also permit the tightest known analysis of popular iterative algorithms such as CoSaMP and Subspace Pursuit.

Stochastic optimization

Fri.1.MA 141

Progressive hedging: Innovations and applications

Organizer/Chair David Woodruff, UC Davis · Invited Session

David Woodruff, UC Davis (with Jean-Paul Watson, Roger Wets)

Bundling scenarios in progressive hedging

In this paper, we provide theoretical background and describe computational experience with schemes for *bundling* scenarios to improve convergence rates and reduce computational effort for Progressive Hedging (PH). Although the idea was floated (Wets 89, Wets 91) at about the same time PH was first described, it has received very little attention. As we will show, bundling can be an important component in PH. We provide brief introduction to stochastic programming problems and their solution via PH. Theoretical justification and guidance for scenario bundling is introduced. Computational experiments with scenario bundling are described.

Jia Kang, Texas A&M University (with Carl Laird, Jean-Paul Watson, David Woodruff, Daniel Word)

Parallel solution of structured nonlinear problems using Pyomo and PySP

Nonlinear programming has proven to be an effective tool for dynamic optimization, parameter estimation, and nonlinear stochastic programming. However, as problem sizes continue to increase, these problems can exceed the computing capabilities of modern desktop computers using serial solution approaches. Block structured problems arise in a number of areas, including nonlinear stochastic programming and parameter estimation. Pyomo, an open-source algebraic modeling language, and PySP, a python-based stochastic programming framework, are used to formulate and solve these problems in parallel. In this work, we compare two approaches for parallel solution of these problems. Rockafellar and Wets' progressive hedging algorithm is used to efficiently solve large-scale parameter estimation problems in parallel with IPOPT (a nonlinear interior-point package) used as the sub-problem solver. As well, an internal decomposition approach that solves the structured linear KKT system in parallel is also used. We compare these parallel solution approaches with serial methods and discuss our experience working within Pyomo and PySP.

Jean-Paul Watson, Sandia National Laboratories (with Roger Wets, David Woodruff)

Asynchronous progressive hedging

Progressive Hedging (PH) is a scenario-based decomposition strategy for solving multi-stage stochastic programs. An attractive feature of PH is the ease with which it can be parallelized, by assigning sub-problems to each of many available processors; sub-problems

may be linear programs, mixed-integer linear programs, or non-linear programs. The PH algorithm as stated parallelizes synchronously, in that all scenario sub-problems are solved before averages and sub-gradients are computed. However, for large-scale parallelization, such barrier synchronization leads to poor parallel efficiency, especially as sub-problem solve time variability increases. To mitigate this issue, we introduce the Asynchronous Progressive Hedging (APH) algorithm, where updates are done without waiting for all scenario sub-problem solves to complete. APH is critical on parallel computing architectures that are inherently heterogeneous and unreliable, or when so many compute nodes are employed that at least one of them is likely to fail during execution. We show that key convergence properties of PH hold in APH, and report computational experiences on mixed-integer linear and non-linear stochastic programs.

Stochastic optimization

Fri.1.MA 144

Stochastic network design and reliability

Organizer/Chair Nedialko Dimitrov, Naval Postgraduate School · Invited Session

Paul Kantor, Rutgers University (with Endre Boros, Fred Roberts, Brian Thompson)

Layered screening at public events: Models and challenges

Public events must screen against many threats. Stakeholders' interests diverge – owners seek revenue, patron experience, and safety against minor disturbances, and major attacks. Patrons seek to enjoy the game, to drink, etc. Events are protected by layers of agents (county police, city police, stadium workers etc.) under distinct authorities, and each with its own screens. For each "violation" there are several terminal remedies. A guest with a knife, or beer may be asked to surrender the object, or to go home. A cost matrix $C(\alpha, s; J)$ depends on the state of the patron (s =harmless; ... etc.) and the terminal action imposed by the authorities (α =confiscate but admit; send home; arrest; etc.), as seen by stakeholder class J .

Given imperfect screens (metal detector; wandering; dogs; pat-down; etc.) we seek optimal routing rules for arriving patrons. Assignment to further screens, and choice of actions, depends on results of earlier screens. One screened for metal may be labeled [admit; wand; pat-down; etc.]. We need throughput for all patron classes, with acceptable costs for all. We give a polytope approach, a dynamic programming approach, rigorous results, and simulations.

Christian Klaus, Naval Postgraduate School (with Nedialko Dimitrov)

Increasing network reliability by introducing warehouses

Humanitarian assistance cargo is shipped by filling available space on regularly scheduled transportation routes. Regularly scheduled transportation can be modeled as a network consisting of source, destination, and transshipment nodes, where the edges represent the scheduled transportation routes. The edge capacities are discrete random variables, the space available on a particular mission. An empirical distribution of the capacities can be obtained from historical data. Because of the stochastic nature of the network, an analysis of the network's reliability in shipping cargo is done by sampling. The analysis shows insufficient ability to deliver the cargo. In order to increase the reliability of the network to ship cargo, we consider creating warehouses on selected transshipment nodes, where goods can be stored until space for further shipment is available. The introduction of the warehouses can be modeled using a network with multiple time layers. We address the question of how to select the best warehouse. The problem can be modeled as a two stage stochastic program, where the first stage decision variables select warehouse locations, including storage capacity.

Melih Çelik, Georgia Institute of Technology (with Ozlem Ergun, Pinar Keskinocak)

The post-disaster debris clearance problem with uncertain debris amounts

In this study, we focus on the clearance stage of post-disaster debris management process, which spans the first few days following the disaster, when clearance resources are extremely limited. Given that a set of roads in the network are blocked, the objective is to determine the road clearance sequence in each period so that the total expected penalty due to unsatisfied relief commodity demand over all periods is minimized. We assume that the amount of debris to be cleared is known for only a certain set of blocked roads, where as for the remaining roads, initial beliefs exist and are updated as clearance proceeds. For this problem, we formulate a Partially Observable Markov Decision Process (POMDP) model to find the optimal solutions, and explore performance bounds compared to the case of solving a deterministic model with expected debris amounts. Due to the high computational burden of applying the POMDP model, we propose a heuristic procedure based on sampling of alternative actions and possible observations of actual debris amounts. We test the performance of this procedure on randomly and structurally generated instances on certain types of graphs.

Telecommunications & networks

Fri.1.H 3002

Optimization modeling of communication networks

Organizers/Chairs Michal Pioro, Warsaw University of Technology; Deep Medhi, University of Missouri-Kansas City · Invited Session

Michal Pioro, Warsaw University of Technology (with Dritan Nace, Artur Tomaszewski, Mateusz Zotkiewicz)

On a survivable network design problem with one or two failing links and elementary path-flows

A well known problem in survivable network design consists in minimizing the cost of links under a single link failure scenario (any link can fail but only one at a time) assuming flow restoration. The problem, denoted by FR, assumes bifurcated primary and restoration flows, and stub release (the capacity of links released by failing flows is used for restoration). FR can be expressed as a linear program but only in a non-compact formulation with NP-hard separation. Because of that, FR is regarded as NP-hard itself although this has not been proved. The paper considers a version of FR when only one predefined link or only two predefined links can fail. We assume that the primary paths cannot contain loops – an assumption commonly neglected. We show that the case with one failing link is polynomial while the case with two failing links is NP-hard. This is a new result that sheds light on FR also for the single link failure scenario. As a byproduct of the one-failing link case, we obtain an example of a non-compact LP formulation with NP-hard separation which actually describes a polynomial problem. Such an example has not been commonly known to the network design community before.

Giuliana Carello, Politecnico di Milano (with Bernardetta Addis, Federico Malucelli)

A network loading problem with shared protection and SRG: Formulations and ILP based hybrid heuristics

Failure resiliency is an important issue in telecommunication networks. In real networks different links may share physical structures and therefore may be affected by the same physical fault. This complexity is captured by Shared Risk Groups (SRGs), which represent sets of links affected by the same fault. We focus on a shared protection scheme, according to which the backup capacity can be shared among different demands, provided that they are not affected by the same faults. We address a network loading problem where SRG and shared protection are considered. We propose a couple of mathematical models. As the problem seems extremely challenging from the computational point of view, we explore the possibility of adding some valid inequalities that have been successful in standard network design problem. Besides, we present some ILP based hybrid heuristic approaches. One approach considers the dynamic addition of constraints, while the other approach is based on a combination of greedy and local search. We report an extensive experimental comparison of all the proposed approaches.

Uwe Steglich, Chemnitz University of Technology (with Thomas Bauschert)

Robust multi-layer network design under traffic demand uncertainty

We present a mixed-integer linear programming approach for a multi-layer network design problem under traffic demand uncertainty. This problem arises in the planning of IP (Internet Protocol) based networks, where the IP routers are interconnected by logical links that are paths in an underlying transport network. The transport network in turn might consist of different layers and technologies, e.g., an OTN layer (with electrical switching capability on ODU granularity) and a DWDM layer (with pure optical switching capability on wavelength granularity) which allows for optimum grooming and layer bypassing. Demand uncertainty results from daytime usage fluctuations, user behavior and external effects like BGP route flapping or server load balancing mechanisms and is regarded as big challenge for network operators. Our work is based on modifications of the Γ -robust design approach and the "Path over Path" concept for multi-layer planning. Contrary to existing approaches our model considers multi-path routing, traffic grooming and layer skipping in parallel. We report computational results and limitations for realistic network scenarios and different transport network realizations.

Telecommunications & networks

Fri.1.H 3503

Robust and survivable network design

Organizer/Chair Fabio D'Andreagiovanni, Zuse Institute Berlin (ZIB) · Invited Session

Christian Raack, Zuse Institute Berlin

Cutset inequalities for robust network design

In order to create and operate resource- and cost-efficient networks the uncertainty of traffic demand (data, passengers) has to be taken into

account already in the strategic capacity design process. A promising approach is robust optimization (RO).

Network design problems in telecommunications or public transport are often solved using Mixed Integer Programming (MIP) models based on multi-commodity-flow formulations. It is known that the solution process can be sped up if strong valid inequalities based on network cuts, so-called cutset inequalities, are used as cutting planes.

In this work, combining methods from RO and MIP, we study the impact of cutset inequalities in solving robust network design problems. We assume that traffic demands are given as a polyhedral set and present facet proofs for different variants of these inequalities in different variable spaces thereby generalizing the deterministic single scenario case. We show that robust cutset inequalities are independent of the chosen recourse scheme (static or dynamic routing). We also report on computational tests showing a significant speed-up for standard solvers such as CPLEX.

Agustin Pecorari, Universidad de Buenos Aires (with Irene Loiseau)

Models for p -cycle networks design without cycle enumeration

A major issue for telecommunication networks is to be cost efficient with a high level of quality of service. A network is said survivable if it is operational even if certain component fails, that is, if it is still able to provide communication between sites it connects. Mesh restoration schemes were widely used in the 1970s and early 1980s. Ring based topologies were introduced in the late 80s based on self-healing rings (SHR) networks technology. Around ten years later appeared the p -cycle networking concept. A single unit capacity p -cycle is a cycle composed of one spare channel on each span it crosses. So a p -cycle provides one protection path for a failed span and it also protects spans that have both end nodes on the cycle but are not themselves on the cycle. The problem we deal with may be seen as the problem of covering with p -cycles all the demands on a 2-connected graph minimizing the total cost. We propose four new compact ILP and MIP models for this problem. They were tested in standard benchmark cases and on a set of networks representing real USA telecommunication networks. Results were competitive with those of previous work and in several cases improved them.

Di Yuan, Linköping University (with Iana Siomina)

Cell load coupling in planning and optimization of LTE networks

This presentation considers a system model that characterizes the coupling relation among cell load levels in Orthogonal frequency division multiple access for long term evolution (LTE) broadband mobile networks. The model takes into account non-uniform traffic demand and the load-dependent interference. Solving the system model enables a network-wide performance evaluation in terms of resource efficiency. We provide a summary of the key mathematical properties of the model. The properties allow for designing powerful means for performance assessment in network planning and optimization. The theoretical insights are accompanied by an illustration of applying the model in load balancing of heterogeneous LTE networks via range optimization of pico-cells.

Variational analysis

Fri.1.H 2035

Variational-analytic foundations of sensitivity analysis

Chair Dmitriy Drusvyatskiy, Cornell University

Shanshan Zhang, Cornell University (with Adrian Lewis)

Partial smoothness, tilt stability, and generalized Hessians

We compare two recent variational-analytic approaches to second-order conditions and sensitivity analysis for nonsmooth optimization. We describe a broad setting where computing the generalized Hessian of Mordukhovich is easy. In this setting, the idea of tilt stability introduced by Poliquin and Rockafellar is equivalent to a classical smooth second-order condition.

Iqbal Husain, Jaypee University of Engineering and Technology, Guna, M.P, India (with Santosh Srivastav)

On second-order Fritz John type duality for variational problems

A second-order dual to a variational problem is formulated. This dual uses the Fritz John type necessary optimality conditions instead of the Karush-Kuhn-Tucker type necessary optimality conditions and thus, does not require a constraint qualification. Weak, strong, Mangasarlian type strict-converse, and Huard type converse duality theorems between primal and dual problems are established. A pair of second-order dual variational problems with natural boundary conditions is constructed, and it is briefly indicated that the duality results for this pair can be validated analogously to those for the earlier models dealt with in this research. Finally, it is pointed out that our results can be viewed as

the dynamic generalizations of those for nonlinear programming problems, already treated in the literature.

Dmitriy Drusvyatskiy, Cornell University (with Adrian Lewis)

Identifiability and the foundations of sensitivity analysis

Given a solution to some optimization problem, an identifiable subset of the feasible region is one that captures all of the problem's behavior under small perturbations. Seeking only the most essential ingredients of sensitivity analysis leads to identifiable sets that are in a sense minimal. In particular, critical cones – objects of classical importance – have an intuitive interpretation as tangential approximations to such sets. I will discuss how this new notion leads to a broad (and intuitive) variational-analytic foundation underlying active sets and their role in sensitivity analysis.

Variational analysis

Fri.1.H 2051

Generalized differentiation and applications

Organizers/Chairs Vera Roschina, University of Ballarat; Robert Baier, University of Bayreuth · Invited Session

Diethard Pallaschke, Karlsruhe Institute of Technology (KIT) (with Ryszard Urbanski)

Quasidifferentiable calculus and minimal pairs of compact convex sets

The quasidifferential calculus developed by V.F. Demyanov and A.M. Rubinov provides a complete analogon to the classical calculus of differentiation for a wide class of non-smooth functions. Although this looks at the first glance as a generalized subgradient calculus for pairs of subdifferentials it turns out that, after a more detailed analysis, the quasidifferential calculus is a kind of Fréchet-differentiations whose gradients are elements of a suitable Minkowski–Rådström–Hörmander space. Since the elements of the Minkowski–Rådström–Hörmander space are not uniquely determined, we mainly focused our attention to smallest possible representations of quasidifferentials, i.e. to minimal representations.

Adil Bagirov, University of Ballarat (with Alia Al Nuaimat, Napsu Karmitsa, Nargiz Sultanova)

Subgradient methods in nonconvex nonsmooth optimization

The subgradient method is known to be the simplest method in non-smooth optimization. This method requires only one subgradient and function evaluation at each iteration and it does not use a line search procedure. The simplicity of the subgradient method makes it very attractive. This method was studied for only convex problems. In this talk we will present new versions of the subgradient method for solving non-smooth nonconvex optimization problems. These methods are easy to implement. The efficiency of the proposed algorithms will be demonstrated by applying them to the well known nonsmooth optimization test problems.

Vladimir Goncharov, Universidade de Evora (with Giovanni Colombo, Boris Mordukhovich)

Well-posedness of minimal time problem with constant convex dynamics via differential properties of the value function

We consider a general minimal time problem with a constant convex dynamics in a (reflexive) Banach space, which can be seen as a mathematical programming problem. First, we obtain a general formula for the minimal time projection onto a closed set in terms of the duality mapping associated with the dynamics. Based on this formula we deduce then necessary and sufficient conditions of existence and uniqueness of a minimizer in terms of either dynamics rotundity (equivalently, smoothness of the dual set) or differential properties of the target. In both cases the (Fréchet) differentiability of the value function is extremely relevant. Some counter-examples are presented.

Approximation & online algorithms

Fri.2.H 3010

Scheduling and online algorithms

Chair Chris Potts, University of Southampton

Liliana Grigoriu, University Siegen/Politehnica University Bucharest (with Donald Friesen)

Scheduling on uniform processors with at most one downtime on each machine

When scheduling on parallel machines, these may exhibit periods of unavailability due to maintenance or failures, or to due jobs that must execute at predefined times. We consider the problem of non-preemptively scheduling a given set of independent tasks on uniform processors with predefined periods of unavailability, with the aim of minimizing the maximum completion time. This problem is strongly NP-hard. For the case when there is at most one downtime on each machine, we give a simple polynomial Multifit-based approximation algorithm, the schedules of which finish within 1.5 the maximum between

the end of the optimal schedule and the latest end of a downtime. Even for same-speed processors, no polynomial algorithm can insure a better worst-case bound unless $P = NP$. The time complexity of the algorithm is $O(n \log n + (m \log m + nm) \log(\sum_{X \in T} l(X) + y_{\min}))$, where n is the number of tasks, m is the number of processors, T is the set of tasks, $l(X)$ is the time needed to process task X on the slowest processor, and y_{\min} is the earliest end of a downtime.

Truls Flatberg, SINTEF Technology and Society

Online bin covering with lookahead and bounded space

We consider a problem motivated from a practical packing problem in the fish industry. As fish arrive on the packing line their weight and quality are registered, thus giving a lookahead on the items to be packed by robots into identical crates with a required minimum total weight. This problem can be modeled as an online bin covering problem with lookahead and bounded space. The focus of this study was to examine the effect of the lookahead on the quality of the packing. That is, if we know the weight of the N next items, how does the solution quality vary with N as we go from an online problem towards the offline problem. We examined the question by implementing a few simple algorithms and testing them on data based on the real world planning problem.

Chris Potts, University of Southampton (with Nicholas Hall, Marc Posner)

On-line production planning to maximize on-time orders

We consider a production planning environment with two planning periods. Detailed planning occurs in the first period, where complete information is known about a set of orders that are available at the start of this period. An additional set of orders becomes available at the start of the second planning period. The objective is to maximize the value associated with the proportion of orders that complete processing by their due dates. We derive an upper bound on the competitive ratio of any algorithm, relative to the performance of an algorithm with perfect information about the second set of orders. This ratio depends on the relative lengths of the two planning periods. We describe a simple, efficient algorithm that delivers a solution which asymptotically achieves this upper bound ratio as the number of jobs becomes large.

Combinatorial optimization

Fri.2.H 3004

Packing, covering and domination I

Organizer/Chair Annegret Wagler, University Blaise Pascal (Clermont-Ferrand II)/CNRS · Invited Session

Annegret Wagler, University Blaise Pascal (Clermont-Ferrand II)/CNRS (with Gabriela Argiroffo)

Generalized row family inequalities for the set covering polyhedron

Set packing and set covering are dual concepts in combinatorial optimization. The associated polyhedra, the set covering polyhedron SCP and the set packing polyhedron SPP, turned out to have strong similarities. Many classical concepts have been transferred from SPP to SCP, see, e.g., Balas & Ng (1989), Cornuéjols & Sassano (1989), Nobili & Sassano (1989) and Sassano (1989). Recently, row family inequalities have been introduced for SCP by Argiroffo & Bianchi (2010) as a counterpart of clique family inequalities for SPP. While clique family inequalities are valid for SPP in general by Oriolo (2004), row family inequalities are valid for SCP only under certain conditions, but several known cases of facets for SCP fall into this class, see Argiroffo & Bianchi (2010). We extend the class of row family inequalities for SCP, along a generalized concept for clique family inequalities by Pêcher & Wagler (2006) for SPP. We show that generalized row family inequalities provide a large class of constraints being valid for SCP in general, and discuss its potential for strengthening linear relaxations of SCP and describing SCP in terms of facet-defining inequalities.

Gabriela Argiroffo, Universidad Nacional de Rosario (with Silvia Bianchi, Annegret Wagler)

The identifying code polyhedron of cycles

A subset C of vertices of a graph G is an identifying code of G if C intersects the closed neighbourhood of the vertices of G in different sets. The problem of finding minimum identifying codes arises from natural applications (fault detection in networks, fire detection and group tests, for example) and its study was introduced by Karpovsky, Chakrabarty and Levitin (1998). We define the identifying code polyhedron of G as the convex hull of the integer solutions of $M(G)x \geq 1$, where $M(G)$ is the matrix whose rows are the incidence vectors of the closed neighborhood of the vertices of G and their symmetric differences. In this work we present some results on the polyhedral structure of the identifying code polyhedron of a graph. In particular, this approach allows us to find a lower bound for the minimum cardinality of an identifying code of a graph that is tight for even paths and even cycles. We identify valid inequalities for the identifying code polyhedron of an arbitrary graph G .

Finally, we study the identifying code polyhedron of cycles. In particular we identify their $\{0, 1, 2\}$ facet defining inequalities.

Petru Valicov, LaBRI, University of Bordeaux (with Florent Foucaud, Sylvain Gravier, Reza Naserasr, Aline Parreau)

Complexity of identifying codes in some subclasses of perfect graphs

An identifying code C of a graph $G = (V, E)$ is a subset of vertices of G such that it is a dominating set and every vertex of G is identified within C . Formally speaking, let $N[x]$ be the closed neighbourhood of a vertex x then $\forall x \in V, N[x] \cap C \neq \emptyset$ and $\forall u, v \in V, N[u] \cap C \neq N[v] \cap C$. The concept of identifying codes was introduced by Karpovsky et al. in 1998 and since then became a well-studied one.

Determining the size of a minimum identifying code of a graph G (denoted $\gamma^I(G)$) was previously proved to be NP-complete even for restricted classes of graphs. We prove that the edge-identifying code problem i.e. identifying code problem in line graphs is NP-complete even for the class of planar bipartite graphs of maximum degree 3 and arbitrarily large girth while the problem can be solved in linear time for graphs of bounded tree-width. As a corollary of this result we derive that the identifying code problem is NP-complete in a restricted subclass of perfect planar graphs. Moreover, for another family of perfect graphs - split graphs, the problem of computing the size of a minimum identifying code remains NP-complete.

Combinatorial optimization

Fri.2.H 3005

Nonlinear combinatorial optimisation problems I

Organizer/Chair Adam Letchford, Lancaster University · Invited Session

Frank Baumann, TU Dortmund (with Sebastian Berckey, Christoph Buchheim)

Exact algorithms for combinatorial optimization problems with submodular objective functions

Many combinatorial optimization problems have natural formulations as submodular minimization problems over well-studied combinatorial structures. A standard approach to these problems is to linearize the objective function by introducing new variables and constraints, yielding an extended formulation. We propose two new approaches for constrained submodular minimization problems. The first is a linearization approach that requires only a small number of additional variables. We exploit a tight polyhedral description of this new model and an efficient separation algorithm. The second approach uses Lagrangean decomposition to create two subproblems which are solved with polynomial combinatorial algorithms; the first subproblem corresponds to the objective function while the second consists of the constraints. The bounds obtained from both approaches are then used in a branch and bound-algorithm. We apply our general results to problems from wireless network design and mean-risk optimization. Our experimental results show that both approaches compare favorably to the standard techniques.

Frauke Liers, Friedrich-Alexander University Erlangen-Nuremberg (with Bernhard Stöcker)

A polyhedral approach to the quadratic matching problem

In the quadratic matching (QM) problem, we are given a real cost for each edge in a graph. Furthermore, for each pair of edges a real cost is specified as well. The task is to determine a (not necessarily perfect) matching that minimizes its associated cost, i.e., the sum of the costs of the matched edges plus the sum of the product costs for any pair of matched edges. The QM problem is closely related to classical combinatorial optimization tasks such as the quadratic assignment problem. Applications of QM exist in computer vision and, more generally, when 'highly similar' subgraphs of two graphs shall be determined. In this work, we study the polyhedral structure of the corresponding QM polytope. Based on these results, we design and implement an exact branch-and-cut approach and report computational results.

Vishnu Narayanan, Indian Institute of Technology Bombay

Some properties of integer hulls of convex sets

We study properties of integer hulls of (unbounded) closed convex sets. We examine existence of facets, dimensions of faces and their properties, and derive results on representation of integer hulls using well studied sets. We derive necessary and sufficient conditions for semidefinite representation of these integer hulls.

Combinatorial optimization

Fri.2.H 3012

Vehicle routing

Chair Rafael Martinelli, Pontificia Universidade Católica do Rio de Janeiro (PUC-Rio)

Enrico Bartolini, University of Bologna (with Roberto Baldacci, Aristide Mingozzi)

The single-vehicle dial-a-ride problem

The single-vehicle dial-a-ride problem (SV-DARP) is a generalization of the traveling salesman problem with pickup and delivery (TSPPD) where the travel time between the visit of each pickup and the corresponding delivery cannot exceed a maximum ride time. The SV-DARP has several applications, e.g., in door-to-door transportation services for elderly or disabled people. We propose an exact algorithm that is based on a new mathematical formulation of the SV-DARP involving an exponential number of variables that correspond to the possible paths for each pickup-delivery pair. A valid lower bound is computed by a cut-and-column generation procedure that solves the LP relaxation of the mathematical formulation strengthened by valid inequalities. The resulting lower bound and the corresponding dual solution are used to generate all paths having reduced cost not greater than the gap between the lower bound computed and a known upper bound. The resulting integer problem is solved by means of an integer programming solver. We report on preliminary computational experiments over a large set of SV-DARP instances derived from the main TSPPD benchmark sets.

Rafael Martinelli, Pontificia Universidade Católica do Rio de Janeiro (PUC-Rio) (with Diego Pecin, Marcus Poggi)

Efficient restricted non-elementary route pricing for routing problems

Column generation is present in the current most efficient approaches to routing problems. Set partitioning formulations model routing problems by considering all possible routes and selecting a subset of them that visits all customers. This formulation often produces tight linear relaxation lower bounds and requires column generation for its pricing step. Recently the ng-routes were proposed as a compromise between elementary and non-elementary routes. The ng-routes are non-elementary routes with the restriction that following a customer it is not allowed to visit one that was visited before, if it belongs to a dynamically computed ng-set associated with this first customer. The larger the size of the ng-sets, the closer the ng-route is to an elementary route. This work presents an efficient pricing algorithm for ng-routes, which combines Incremental State-Space Relaxation (DSSR) technique with completion bounds. This allows strengthening the domination rule, drastically reducing the total number of labels. Experimental results are presented for the GVRP and CVRP. We report for the first time experiments with ng-set sizes up to sixty-four obtaining several new best lower bounds.

Combinatorial optimization

Fri.2.H 3013

Facility location

Organizer/Chair Jarosław Byrka, University of Wrocław · Invited Session

Bartosz Rybicki, University of Wrocław (with Jarosław Byrka)

Improved LP-rounding approximation algorithm for k -level uncapacitated facility location

We study the k -level uncapacitated facility location problem, where clients need to be connected with paths crossing open facilities of k types (levels). In this paper we give an approximation algorithm that for any constant k , in polynomial time, delivers solutions of cost at most α_k times OPT , where α_k is an increasing function of k , with $\lim_{k \rightarrow \infty} \alpha_k = 3$.

We improve the approximation ratio for k -UFL for all $k \geq 3$, in particular we obtain the ratio equal 2.02, 2.14, and 2.24 for $k = 3, 4$, and 5.

Sara Ahmadian, University of Waterloo (with Chaitanya Swamy)

Improved approximation guarantees for lower-bounded facility location

We consider the lower-bounded facility location (LBFL) problem, which is a generalization of uncapacitated facility location (UFL), where each open facility is required to serve a minimum amount of demand. More formally, an instance I of LBFL is specified by a set F of facilities with facility-opening costs $\{f_i\}$, a set D of clients, a lower-bound M , and connection costs $\{c_{ij}\}$ specifying the cost of assigning a client j to a facility i . The goal is to open a subset of facilities and assign each client to an open facility, so that each open facility serves at least M clients, in a cost-efficient manner.

We improve the current best approximation ratio for LBFL (550 by Svitkina) to 83. Our improvement comes from a variety of ideas in algorithm design and analysis. Our chief algorithmic novelty is to reduce a more-structured LBFL instance to a problem we introduce, called

capacity-discounted UFL (CDUFL). CDUFL is a special case of capacitated facility location (CFL) where facilities are either uncapacitated, or have finite capacity and zero opening costs. We give a simple local-search algorithm for CDUFL that achieves the approximation ratio of $1 + \sqrt{2}$.

Complementarity & variational inequalities

Fri.2.MA 313

Variational inequality problems: Analysis and computation

Organizer/Chair Vinayak Shanbhag, University of Illinois at Urbana-Champaign · Invited Session

Vinayak Shanbhag, University of Illinois at Urbana-Champaign (with Uma Ravat)

On the analysis and solution of stochastic variational inequalities

We consider the stochastic variational inequality problem in which the mappings contain expectations over a possibly general measure space and associated sets may be unbounded. In this talk, we consider two fundamental questions. First, we provide tractable verifiable conditions for showing existence that do not necessitate integration. Important such conditions are provided for quasi-variational inequalities and complementarity problems and can further accommodate multi-valued maps and nonconvex sets. Second, we discuss some stochastic approximation schemes for monotone stochastic variational inequalities that incorporate regularization and allow for adaptive modifications of steplengths.

Che-Lin Su, University of Chicago Booth School of Business (with Yu-Ching Lee, Jong-Shi Pang)

Estimation of pure characteristics demand models with pricing

A pure characteristics model is a class of discrete-choice random-coefficients demand models in which there is no idiosyncratic logit error term in a consumer's utility. The absence of the logit error term leads to a nonsmooth formulation of the predicted market share equations. As a result, inverting the market share equations for the unobserved product characteristics and estimating the model by using the nested fixed-point approach as proposed in the existing econometrics literature becomes computationally intractable. We introduce lotteries for consumers' purchase decisions, which are then characterized by a system of complementarity constraints. This reformulation leads to smooth market share equations. Based on this reformulation, we then cast the generalized method of moments (GMM) estimation of a pure characteristics model as a quadratic program with nonlinear complementarity constraints. We present numerical results to demonstrate the effectiveness of our approach.

Huifu Xu, University of Southampton (with Yongchao Liu, Werner Römisch)

Quantitative stability analysis of stochastic generalized equations and applications

We consider a stochastic generalized equation (SGE) where the underlying function is the expected value of a random set-valued mapping. SGE has many applications such as characterizing optimality conditions of a nonsmooth stochastic optimization problem and a stochastic equilibrium problem. We derive quantitative continuity of expected value of the set-valued mapping with respect to the variation of the underlying probability measure in a metric space. This leads to the subsequent qualitative and quantitative stability analysis of solution set mappings of the SGE. Under some metric regularity conditions, we derive Aubin's property of the solution set mapping with respect to the change of probability measure. The established results are applied to stability analysis of stationary points of classical one stage and two stage stochastic minimization problems, two stage stochastic mathematical programs with equilibrium constraints and stochastic programs with second order dominance constraints.

Conic programming

Fri.2.H 2036

Algebraic geometry and conic programming II

Organizers/Chairs Cordian Riener, University of Konstanz; Lek-Heng Lim, University of Chicago · Invited Session

Jiawang Nie, University of California, San Diego

Certifying convergence of Lasserre's hierarchy via flat truncation

Consider the optimization problem of minimizing a polynomial function subject to polynomial constraints. A typical approach for solving it globally is applying Lasserre's hierarchy of semidefinite relaxations, based on either Putinar's or Schmüdgen's Positivstellensatz. A practical question in applications is: how to certify its convergence and get minimizers? In this paper, we propose *flat truncation* as a certificate for this purpose. Assume the set of global minimizers is nonempty and finite. Our main results are: (i) Putinar type Lasserre's hierarchy has finite convergence if and only if flat truncation holds, under some generic

assumptions; the same conclusion holds for the Schmüdgen type one under weaker assumptions. (ii) Flat truncation is asymptotically satisfied for Putinar type Lasserre's hierarchy if the Archimedean condition holds; the same conclusion holds for the Schmüdgen type one if the feasible set is compact. (iii) We show that flat truncation can be used as a certificate to check exactness of standard SOS relaxations and Jacobian SDP relaxations.

Jordan Ninin, Laboratory Jean Kuntzmann (with Roland Hildebrand)

Abstract cones of positive polynomials and sums of squares

In [Recent Advances in Optimization and its Applications in Engineering, pp. 41–50, Springer, 2010] we presented a new approach to the construction of sums of squares relaxations, that of *abstract cones of positive polynomials*. In this framework, a fixed cone of positive polynomials is considered as a subset in an abstract coefficient space and corresponds to an infinite, partially ordered set of concrete cones of positive polynomials of different degrees and in a different number of variables. To each such concrete cone corresponds its own SOS cone, leading to a hierarchy of increasingly tighter SOS relaxations for the abstract cone. In the present contribution, we consider further theoretical properties and test the practical performance of this approach. In particular, we propose an alternative method for the construction of SOS relaxations to general polynomially constrained optimization problems and apply it to some classical combinatorial optimization problems which can be cast in a polynomially constrained form.

André Uschmajew, TU Berlin

Convergence of algorithms on quotient manifolds of Lie groups

When it comes to analyzing the (local) convergence properties of algorithms for optimization with respect to certain tensor formats of fixed low rank, such as PARAFAC-ALS or TUCKER-ALS, one is confronted with the non-uniqueness of the low-rank representations, which causes naive contraction arguments to fail. This non-uniqueness is (at least partially) caused by a Lie group action on the parameters of the tensor format (scaling indeterminacy). On the other hand, for instance in the case of ALS, the algorithm has an invariance property (with respect to the Lie group), namely to map equivalent representations to equivalent ones. In this talk we show how these ingredients lead to natural convergence results for the equivalence classes (orbits) of the Lie group, which are the true objects of interest. For subspace tensor formats, such as the Tucker format, the quotient manifold is diffeomorphic to the variety of tensors of fixed subspace rank. For the CP format one has to make additional assumptions. The results are presented in a generality which does not restrict them to the low-rank tensor approximation problem only.

Conic programming

Fri.2.H 2038

Warmstarting interior point methods

Organizer/Chair Jacek Gondzio, University of Edinburgh · Invited Session

Anders Skajaa, Technical University of Denmark (with Erling Andersen, Yinyu Ye)

Warmstarting the homogeneous and self-dual interior point method for linear and conic quadratic problems

We present two strategies for warmstarting primal-dual interior point methods for the homogeneous self-dual model when applied to mixed linear and quadratic conic optimization problems. Common to both strategies is their use of only the final (optimal) iterate of the initial problem and their negligible computational cost. This is a major advantage when comparing to previously suggested strategies that require a pool of iterates from the solution process of the initial problem. Consequently our strategies are better suited for users who use optimization algorithms as black-box routines which usually only output the final solution. Our two strategies differ in that one assumes knowledge only of the final primal solution while the other assumes the availability of both primal and dual solutions. We present extensive computational results showing work reductions when warmstarting compared to coldstarting in the range 30 to 75 percent depending on the problem class and magnitude of the problem perturbation. The computational experiments thus substantiate that the warmstarting strategies are useful in practice.

E. Alper Yildirim, Koc University

Warm-start strategies: What matters more?

The problem of solving a sequence of closely related optimization problems arises frequently in sequential optimization algorithms and branch-and-bound-like schemes. The information gained during the solution of an optimization problem can in principle be used to solve a closely related optimization problem with less computational effort. The proper use of this information constitutes warm-start techniques.

In this talk, our goal is to focus on the criteria in the design of warm-start strategies and to identify which ones are more closely related to the success in practice.

Pablo González-Brevis, University of Edinburgh (with Jacek Gondzio)

A new warm-starting strategy for the primal-dual column generation method

In this presentation a new warm-starting technique in the context of a primal-dual column generation method applied to solve a particular class of combinatorial optimization problems will be addressed. The technique relies on calculating an initial point and on solving auxiliary linear optimization problems to determine the step direction needed to fully restore primal and dual feasibilities after new columns arrive. Conditions on the maximum size of the cuts from the dual perspective and on a suitable initial point will be discussed. This strategy ensures that the duality gap of the warm-start is bounded by the old duality gap and a constant, which depends on the relation between the old and modified problems. Additionally, computational experience using this strategy will be reported.

Derivative-free & simulation-based opt.

Fri.2.H 3003A

Multiple objectives in derivative-free optimization

Organizers/Chairs Stefan Wild, Argonne National Laboratory; Luis Nunes Vicente, University of Coimbra · Invited Session

Francesco Rinaldi, Sapienza University of Rome (with Giovanni Fasano, Giampaolo Liuzzi, Stefano Lucidi)

Using an exact penalty function for multiobjective Lipschitz programs

This work focuses on the solution of a constrained multiobjective optimization problem, with both nonlinear inequality constraints and bound constraints. We assume that the vector of the objective functions and the constraints are Lipschitz continuous. We issue the equivalence between the original constrained multiobjective problem, and a multiobjective problem with simple bounds, by means of an exact penalty function approach. We study the Pareto-Clarke stationary points of the multiobjective problem with bound constraints, and state their correspondence with the Pareto-Clarke stationary points of the original constrained multiobjective problem. We propose a line search based derivative free framework to issue the latter correspondence. We also report some numerical results proving the effectiveness of the proposed approach.

Luis Nunes Vicente, University of Coimbra (with Rui Pedro Brito)

Efficient cardinality/mean-variance portfolios

We propose a novel approach to handle cardinality in portfolio selection, by means of a biobjective cardinality/mean-variance problem, allowing the investor to analyze the efficient tradeoff between return-risk and number of active positions. Recent progress in multiobjective optimization without derivatives allow us to robustly compute (in-sample) the whole cardinality/mean-variance efficient frontier, for a variety of data sets and mean-variance models. Our results show that a significant number of efficient cardinality/mean-variance portfolios can overcome (out-of-sample) the naive strategy, while keeping transaction costs relatively low.

Ana Luisa Custodio, Universidade Nova de Lisboa (with Jose Aguilar Madeira, A. Ismael F. Vaz, Luis Nunes Vicente)

Direct MultiSearch: A robust and efficient approach to multiobjective derivative-free optimization

In practical applications it is common to have several conflicting objective functions to optimize. Frequently, these functions exhibit nondifferentiabilities, are subject to numerical noise or are of black-box type, requiring the use of derivative-free optimization techniques.

In 2011 we proposed a multiobjective derivative-free methodology, called Direct MultiSearch (DMS), suited for this type of applications, which generalizes to multiobjective optimization all direct-search methods of directional type. DMS is based on the search/poll framework, but uses the concept of Pareto dominance to maintain a list of nondominated points and to define a successful iteration.

Under the common assumptions used in direct-search for single objective optimization, and without considering any aggregation function for the several objectives involved in the problem definition, we proved that at least one limit point of the sequence of iterates generated by DMS lies in (a stationary form of) the Pareto front. Extensive computational experience has shown, however, that DMS has an impressive capability of generating the whole Pareto front.

Finance & economics

Fri.2.H 3021

Risk management under probability model misspecification

Organizers/Chairs Apostolos Fertis, ETH Zurich; Victor Demiguel, London Business School · Invited Session

David Wozabal, Technische Universität München

Robustifying convex risk measures: A non-parametric approach

We introduce a framework for robustifying portfolio selection problems with respect to ambiguity in the distribution of the random asset losses. In particular, we are interested in convex, version independent risk measures. We use an ambiguity set which is defined as a neighborhood around a reference probability measure which represents the investors beliefs about the distribution of asset losses. The robustified risk measures are defined as the worst case portfolio risk over the ambiguity set of loss distributions. We demonstrate that under mild conditions, the infinite dimensional optimization problem of finding the worst case risk can be solved analytically and consequently closed form expressions for the robust risk measures are obtained. We use these results to derive robustified version for several examples of risk measures. The resulting robust policies are computationally of the same complexity as their non-robust counterparts. We conclude with a numerical study that shows that in most instances the robustified risk measures perform significantly better out-of-sample than their non-robust variants in terms of risk, expected losses as well as turnover.

Victor Demiguel, London Business School (with Francisco Nogales, Raman Uppal)

Stock return serial dependence and out-of-sample portfolio performance

We study whether investors can exploit stock return serial dependence to improve the out-of-sample performance of their portfolios. To do this, we first show that a vector autoregressive (VAR) model captures daily stock return serial dependence in a statistically significant manner. Second, we characterize (analytically and empirically) the expected return of an arbitrage (zero-cost) portfolio based on the VAR model, and show that it compares favorably to that of other arbitrage portfolios in the literature. Third, we evaluate the performance of three investment (positive-cost) portfolios: a conditional mean-variance myopic portfolio obtained using the linear VAR model; a conditional mean-variance portfolio using a nonparametric autoregressive (NAR) model; and, a portfolio that is dynamic rather than myopic in its use of the VAR model. We show that, subject to a suitable norm constraint, all three investment portfolios substantially outperform the traditional (unconditional) portfolios, even in the presence of transaction costs of up to 10 basis points.

Finance & economics

Fri.2.H 3027

Generalized nash equilibrium problems

Organizer/Chair Kenneth Judd, Hoover Institution · Invited Session

Philipp Renner, Universität Zürich (with Eleftherios Couzoudis)

Computing generalized Nash equilibria by polynomial programming

We present a new way to solve generalized Nash equilibrium problems. We assume the feasible set to be closed and compact. Furthermore all functions are assumed to be rational. However we do not need any convexity assumptions on either the utility functions or the action sets. The key idea is to use Putinar's Positivstellensatz, a representation result for positive polynomials. We obtain a system of polynomial equations and inequalities. The solutions to this are all within epsilon to be optimal. In many situations epsilon is zero.

Frits Spieksma, KU Leuven (with Bart Smeulders)

Testing rationality: algorithms and complexity

Micro-economic theory offers non-parametric tests that show whether observed data are consistent with a model of utility maximization. For instance, it is well-known that, given a dataset, it can be efficiently tested whether the generalized axiom of revealed preference (GARP) holds. The outcome of such a test is binary: data either satisfy GARP or they don't. An implication of such an approach is that when the data do not pass the test, there is no indication concerning the severity or the amount of violations. A number of approaches have been proposed in the literature to express how close a dataset is to satisfying rationality. One popular approach is Afriat's efficiency-index. Several alternative measures have been proposed, amongst others by Houtman and Maks, and by Varian. For the latter two indices, it is empirically recognized in the literature that finding these measures is computationally intensive. We show that computing these maximum efficiency-indices is an NP-hard problem. We also show that no constant-factor approximation algorithm exists for the Houtman-Maks index unless P = NP.

Finally, we give an exact polynomial time algorithm for finding the Afriat index.

Eleftherios Couzoudis, Universität Zürich

Finding all generalized Nash equilibria

Often a generalized Nash equilibrium problem has infinitely many solutions and commonly the solution set isn't connected. The current method is then to only compute the normalized equilibrium in which the Lagrange multipliers are equal. This is only one solution out of the set of normalized equilibria which is a subset of the solution set. For problems with linear constraints an approach is shown where all solutions are given as a union of sets. For this a modified simplex algorithm is used to yield a vertex representation of the equilibrium subsets. The implementation is then used to compute some popular examples.

Game theory

Fri.2.MA 005

Competition on networks

Organizers/Chairs Nicolas Stier-Moses, Columbia University; Jose Correa, Universidad de Chile · Invited Session

Evdokia Nikolova, Texas A&M University (with Nicolas Stier-Moses)

A mean-risk model for the stochastic traffic assignment problem

We embark on an agenda to investigate how stochastic travel times and risk aversion transform the traditional traffic assignment problem and its corresponding equilibrium concepts. Moving from deterministic to stochastic travel times with risk-averse users introduces non-convexities that make the problem more difficult to analyze. For example, even computing a best response of a user to the environment is still of unknown complexity. This paper focuses on equilibrium existence and characterization in the different settings of infinitesimal (non-atomic) vs. atomic users and fixed (exogenous) vs. congestion-dependent (endogenous) variability of travel times. Because cost functions are non-additive, solutions need to be represented as path flows. Nevertheless, we show that succinct representations of equilibria and optimal solutions always exist. We also obtain that under exogenous variability of travel times, the worst-case inefficiency of equilibria (the price of anarchy) is exactly the same as when travel time functions are deterministic, meaning that in this case risk-aversion under stochastic travel times does not further degrade a system in the worst-case.

Nicolas Stier-Moses, Columbia University (with Yoni Gur)

The competitive facility location problem in a duopoly: Advances beyond trees

We consider a competitive facility location game on a network where consumers located on vertices wish to connect to the nearest facility. Knowing this, competitors place facilities on vertices to maximize market share. Focusing in the two-player case, we study conditions that guarantee the existence of pure-strategy Nash equilibria for progressively more complicated networks. The case of trees, which extends the classic Hotelling model, is well-studied: equilibria are characterized by centroids of the tree. We find that cycles admit equilibria when there are vertices with sufficiently big demands. For a general graph, we construct a tree of maximal bi-connected components and apply the results for trees and cycles to get sufficient conditions for equilibrium existence. This provides a complete and efficient characterization of equilibria for networks where the central bi-connected component is a vertex or a cycle. We quantify the maximum inefficiency of equilibria with bounds that depend on topological parameters of the network. These bounds rely on trees, which are worst instances because for these games removing an edge from a graph always increases consumer cost.

Fernando Ordóñez, Universidad de Chile (with Tomas Spencer)

Stackelberg security games on networks

Stackelberg games have recently been used in security applications to decide optimal patrolling strategies in the presence of strategic adversaries that can monitor the security actions prior to deciding on how and where to attack. By using column generation and other decomposition methods we have been able to solve large enough problems to consider interesting real world situations.

These methods, however, break down as the number of adversary actions grows. In this work we consider the problem of patrolling a network where we decide the optimal location of fixed guards and the adversaries select a feasible path to attack. We develop decomposition algorithms to solve this problem and study the conditions for this algorithm to be exact. In particular we show that in the non zero sum case this standard decomposition method can get stuck on a sub-optimal solution.

Game theory

Fri.2.MA 043

Equilibria in congestion games

Chair Max Klimm, Technische Universität Berlin

Philipp von Falkenhausen, Technische Universität Berlin (with Tobias Harks)

Optimal cost sharing protocols for matroid congestion games

We study the design of cost sharing protocols for weighted congestion games where the strategy spaces are either singletons or bases of a matroid. Our design goal is to devise protocols so as to minimize the resulting Price of Anarchy (PoA) and Price of Stability (PoS). We investigate three classes of protocols: basic protocols guarantee the existence of a pure Nash equilibrium, separable protocols additionally work with locally incomplete information on the players' choices, uniform protocols additionally even work with locally incomplete information on the available resources. For singleton games, we prove that among all basic and separable protocols, there is an *optimal* separable protocol minimizing the resulting PoS and PoA simultaneously at the value of $\mathcal{H}_n = \sum_{i=1}^n 1/i$ for n -player games. For matroid games, we show again an optimal basic protocol yielding the n th harmonic number \mathcal{H}_n for PoS and PoA. For separable protocols and matroids, however, we find a structural difference when minimizing the PoA: we devise an optimal separable protocol with PoA of n . For uniform protocols we show that the PoA is unbounded even for singleton games.

Thomas Pradeau, Université Paris-Est (with Frédéric Meunier)

Uniqueness of equilibrium on rings

We consider congestion games on networks with nonatomic users in the multiclass case, i.e., when the cost functions are not the same for all users. We are interested in the *uniqueness property* defined by Milchtaich [Milchtaich, I. 2005. Topological conditions for uniqueness of equilibrium in networks. *Math. Oper. Res.* 30, 225–244] as the uniqueness of equilibrium flows for all assignments of strictly increasing cost functions. He settled the case of two-terminal networks.

In the present work, we characterize completely bidirectional rings for which the uniqueness property holds. The main result is that it holds precisely for five networks and those obtained from them by elementary operations. For other bidirectional rings, we exhibit affine cost functions yielding to two distinct equilibrium flows. We derive moreover nontrivial corollaries concerning the uniqueness property for general networks.

Max Klimm, Technische Universität Berlin (with Tobias Harks, Martin Hoefer, Alexander Skopalik)

Existence and computation of equilibria in bottleneck congestion games

Congestion games are an elegant and well studied model to investigate the effects of resource allocations by selfish agents. In a congestion game each player chooses a subset of resources and her private cost is the sum of the costs of the chosen resources. While the existence of equilibria as well as the complexity of their computation for this class of games is relatively well understood, much less is known for bottleneck congestion games. Here, the private cost of each player equals the maximum cost of all chosen resources. This class of games is motivated by data routing applications where the total delay of a user is closely related to the performance of the weakest link. We show that bottleneck congestion games always admit a pure strong equilibrium – a strengthening of the pure Nash equilibrium concept that is even resilient against coordinated deviations of coalitions of players. Further, we discuss cases, in which strong equilibria can be computed efficiently as well as related hardness results.

Global optimization

Fri.2.H 0110

Algorithms and applications

Organizer/Chair Ernesto G. Birgin, University of São Paulo · Invited Session

Leandro Prudente, State University of Campinas (with Ernesto Birgin, José Mario Martínez)

An augmented Lagrangian method with finite termination

We will present a new algorithm based on the Powell-Hestenes-Rockafellar Augmented Lagrangian approach for constrained global optimization. Possible infeasibility will be detected in finite time. Furthermore, we will introduce a practical stopping criterion that guarantees that, at the approximate solution provided by the algorithm, feasibility holds up to some prescribed tolerance and the objective function value is the optimal one up to tolerance ϵ . At first, in this algorithm, each subproblem is solved with a precision ϵ_k that tends to zero. An adaptive modification in which optimality subproblem tolerances depend on current feasibility and complementarity will also be given. The adaptive algorithm allows one to detect possible infeasibility without requiring to solve subproblems with increasing precision. In this way, we aim rapid

detection of infeasibility, without solving expensive subproblems with unreliable precision.

Luis Felipe Bueno, University of Sao Paulo (with Ernesto Birgin, Natasa Krejić, José Mario Martínez)

Low order-value approach for solving VaR-constrained optimization problems

In low order-value optimization (LOVO) problems the sum of the r smallest values of a finite sequence of q functions is involved as the objective to be minimized or as a constraint. The latter case is considered in the present paper. Portfolio optimization problems with a constraint on the admissible value-at-risk (VaR) can be modeled in terms of LOVO-constrained minimization. Different algorithms for practical solution of this problem will be presented. Global optimization properties of both the problem and the presented algorithms will be discussed. Using these techniques, portfolio optimization problems with transaction costs will be solved.

Marina Andretta, University of Sao Paulo (with Ernesto Birgin)

Deterministic and stochastic global optimization techniques for planar covering with ellipses problems

We are interested in the problem of planar covering of points with ellipses: we have a set of n demand points in the plane (with weights associated to them), a set of m ellipses (with costs associated to their allocation) and we want to allocate k of these ellipses and cover some demand points to get the maximum profit. The profit is measured by summing the weight of the covered demand points and subtracting the costs of the allocated ellipses. Ellipses can have a fixed angle or each of them can be freely rotated. We present deterministic global optimization methods for both cases, while a stochastic version of the method will also be presented for large instances of the latter case. Numerical results show the effectiveness and efficiency of the proposed methods are presented.

Global optimization

Fri.2.H 2053

Advances in global optimization V

Chair Zulfiya Gabidullina, Kazan (Volga Region) Federal University

Giancarlo Bigi, Università di Pisa (with Antonio Frangioni, Qinghua Zhang)

Beyond canonical DC programs: The single reverse polar problem

We introduce the single reverse polar problem as a novel generalization of the canonical DC problem (CDC), and we extend to the former the outer approximation algorithms based on an approximated oracle, which have been previously proposed for the latter. In particular, we focus on the polyhedral case (PSRP), in which the problem amounts to a linear program with a single bilinear constraint which renders it non-convex. Several important classes of nonconvex optimization problems (e.g., bilevel linear, integer and linear complementarity problems) can be easily formulated as a PSRP. In principle, this is true also for CDC, as most nonconvex programs have a DC representation, but the reformulation as a DC program is substantially more difficult to derive. Furthermore, the outer approximation algorithms for PSRP do away with some of the core assumptions required by the algorithms for the CDC case: These assumptions are not trivial to satisfy in practice and indeed cannot hold for some important classes of problems.

Simon Konzett, Universität Wien (with Arnold Neumaier)

Numerical enclosures of solution manifolds at near singular points

This work considers nonlinear real parameter-dependent equations for global optimization. By using interval analysis rigorous enclosures of solution paths dependent on a parameter are determined. Especially the method provides enclosures of (near) singular points of the solution manifold. The method uses an augmentation of the original problem to correct the singularities. Then a low-dimensional problem is deduced of the augmented problem which reflects locally the behaviour of the original problem. In particular the singular behaviour is reflected. The application of the method is illustrated with some numerical results to show the efficiency and robustness of the method.

Zulfiya Gabidullina, Kazan (Volga Region) Federal University

Universal measure of the thickness of separator or pseudo-separator for sets of Euclidean space

At present, different approaches to linear separation of the sets in a finite-dimensional Euclidean space are effectively used in medical diagnostics, discriminant analysis, pattern recognition etc. These approaches represent a particular interest from both theoretical and practical point of view.

In this contributed talk we define a separator and pseudo-separator (the margin of unseparated points of sets) for the sets of Euclidean space by help of generalized supporting hyperplanes. We introduce new universal measure for estimation of the thickness of separator (when

the sets are disjoint) as well as of pseudo-separator (when the sets are inseparable). The optimization problem maximizing the thickness of the separator and minimizing the thickness of the pseudo-separator is considered.

Implementations & software

Fri.2.H 1058

Conic linear programming

Organizer/Chair Christoph Helmberg, TU Chemnitz · Invited Session

Christoph Helmberg, TU Chemnitz (with Kim-Chuan Toh)

Speeding up the spectral bundle method by solving the quadratic semidefinite subproblems with a PSQMR approach

The spectral bundle method is tuned to solving semidefinite programs (SDP) with large semidefinite matrix variables having constant or bounded trace. It exploits that these can be formulated equivalently as problems of minimizing the maximum eigenvalue of affine matrix functions and uses repeated eigenvalue computations to form a semidefinite model of the objective function. The next candidate point is determined as the minimizer of the model plus a quadratic augmenting term. Solving this quadratic semidefinite subproblem by interior point methods formed the bottleneck whenever bundle sizes increased. We report on our experience with a preconditioned symmetric quasi minimal residual (PSQMR) approach for computing the Newton step in this interior point method like in the package QSDP. On our test instances this results in significant savings. Indeed, the cost of the interior point method is then negligible in comparison to the cost of computing the eigenvalues and the cost matrices of the quadratic semidefinite subproblem. In combination with cutting plane approaches, however, results are less favorable and better preconditioning techniques still need to be developed.

Florian Jarre, Universität Düsseldorf (with Thomas Davi)

Solving large scale problems over the doubly nonnegative cone

We consider large scale problems over the doubly nonnegative cone. Under suitable assumptions, regularity of the standard reformulation splitting the doubly nonnegative variable into a semidefinite and a non-negative part can be established. The application of first order methods to this reformulation of problems over the doubly nonnegative cone is motivated by the fact that the cost per iteration does not increase by adding nonnegativity constraints. Preliminary numerical experiments illustrate that even for large scale problems highly accurate numerical solutions can be obtained.

Kim-Chuan Toh, National University of Singapore (with Kaifeng Jiang, Defeng Sun)

An inexact accelerated proximal gradient method for large scale convex quadratic SDP

The accelerated proximal gradient (APG) method has proven to be highly efficient in solving some large scale structured convex optimization (possibly nonsmooth) problems, including nuclear norm minimization problems in matrix completion. The method has superior worst-case iteration complexity over the classical projected gradient method, and usually has good practical performance on problems with appropriate structures. Here, we extend the APG method to the inexact setting where the subproblems are only solved approximately, and show that it enjoys the same worst-case iteration complexity as the exact counterpart if the subproblems are progressively solved to sufficient accuracy. We apply our inexact APG method to solve convex quadratic SDP (QSDP) problems of the form: $\min_x \{ \frac{1}{2} \langle x, Q(x) \rangle + \langle c, x \rangle \mid A(x) = b, x \geq 0 \}$. The subproblem in each iteration is solved by a semismooth Newton-CG (SSNCG) method with warm-start using the iterate from the previous iteration. Our APG-SSNCG method is demonstrated to be efficient for QSDP problems whose positive semidefinite linear maps Q are highly ill-conditioned.

Integer & mixed-integer programming

Fri.2.H 2013

Trends in integer programming

Organizer/Chair Jon Lee, University of Michigan · Invited Session

Amitabh Basu, University of California, Davis (with Robert Hildebrand, Matthias Koeppel, Marco Molinaro)

$A(k+1)$ -slope theorem for the k -dimensional infinite group relaxation

We prove that any minimal valid function for the k -dimensional infinite group relaxation that is piecewise linear with at most $k+1$ slopes and does not factor through a linear map with non-trivial kernel is ex-

treme. This generalizes a theorem of Gomory and Johnson for $k = 1$, and Cornuéjols and Molinaro for $k = 2$.

Siqian Shen, University of Michigan

Bilevel interdiction and risk-and-return tradeoffs in probabilistic programs with single or multiple chance constraints

Chance-constrained programs (CCP) measure value-at-risk of uncertain events, and impose a pre-given tolerance as an upper bound for such a risk. This paper focuses on problems with discretely distributed right-hand-sides in the chance constraints, and trades off risk and cost by also treating risk tolerances as decision variables. We first consider a problem with a single chance constraint in a bilevel interdiction setting, in which a leader decides a risk tolerance, to maximize a follower's objective of a minimization CCP. We show that only a finite number of possible tolerance thresholds matter to the follower's CCP, and interpret the risk tolerance variable as SOS1 binary variables. The bilevel program is then transformed into a deterministic IP. Similar results are used for solving a minimization problem with multiple chance constraints, where each has a risk tolerance variable and the summation of all tolerances is no more than a fixed budget. We develop an IP reformulation with multiple SOS1 binary variables, and solve it via decomposition and modified Benders cuts.

Christopher Ryan, University of Chicago (with Albert Xin Jiang, Kevin Leyton-Brown)

Computing pure Nash equilibria in symmetric games

We analyze the complexity of computing pure strategy Nash equilibria (PSNE) in symmetric games with a fixed number of actions. We restrict ourselves to "compact" representations, meaning that the number of players can be exponential in the representation size. We give polynomial-time algorithms for finding a sample PSNE and counting the number of PSNEs.

Integer & mixed-integer programming

Fri.2.H 2032

Integer points in polytopes I

Organizers/Chairs Michael Joswig, TU Darmstadt; Günter M. Ziegler, FU Berlin · Invited Session

Jesus De Loera, University of California, Davis (with V. Baldoni, N. Berline, M. Koeppel, and M. Vergne)

Top Ehrhart coefficients of knapsack problems

For a given sequence $\mathbf{a} = [a_1, a_2, \dots, a_N, a_{N+1}]$ of $N + 1$ positive integers, we consider the parametric knapsack problem $a_1x_1 + a_2x_2 + \dots + a_Nx_N + a_{N+1}x_{N+1} = t$, where right-hand side t is a varying non-negative integer. It is well-known that the number $E_{\mathbf{a}}(t)$ of solutions in non-negative integers x_i is given by a quasi-polynomial function of t of degree N . For a fixed number k , we give a new polynomial time algorithm to compute the highest $k + 1$ coefficients of the quasi-polynomial $E_{\mathbf{a}}(t)$ represented as step polynomials of t .

Joseph Gubeladze, San Francisco State University

Continuous evolution of lattice polytopes

The sets of lattice points in *normal polytopes*, a.k.a. the *homogeneous Hilbert bases*, model (continuous) convex polytopes. The concept of a normal polytope does not reduce to simpler properties – known attempts include unimodular triangulation and integral Carathéodory properties. To put it in other words, normal polytopes are the monads of quantization of convex shapes. Much work went into understanding special classes of normal polytopes, motivated from combinatorial commutative algebra, toric algebraic geometry, integer programming. In this talk we define a space of *all* normal polytopes. It is generated by certain dynamics, supported by these polytopes. The corresponding evolution process of normal polytopes was used back in the late 1990s to find counterexamples to the mentioned unimodular triangulation and integral Carathéodory properties. On the one hand, this space offers a global picture of the interaction of the integer lattice with normal polytopes. On the other hand, singular points of the space – some known to exist and some conjectural – represent normal point configurations with challenging arithmetic properties.

Gennadiy Averkov, University of Magdeburg (with Christian Wagner, Robert Weismantel)

Lattice-free integer polyhedra and their application in cutting-plane theory

In this talk I will discuss the class of inclusion-maximal lattice-free integer polyhedra. The class is finite in any dimension (modulo transformations that preserve the integer lattice). This finiteness result was proved in a joint work with Christian Wagner and Robert Weismantel and also, independently, by Benjamin Nill and Günter M. Ziegler. I will also discuss consequences of the result for the cutting-plane theory of mixed-integer linear programs.

Integer & mixed-integer programming

Fri.2.H 2033

Cutting plane theory

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Alberto Del Pia, ETH Zürich

On the rank of disjunctive cuts

Let L be a family of lattice-free polyhedra containing the splits. Given a polyhedron P , we characterize when a valid inequality for the mixed-integer hull of P can be obtained with a finite number of disjunctive cuts corresponding to the polyhedra in L . We also characterize the lattice-free polyhedra M such that all the disjunctive cuts corresponding to M can be obtained with a finite number of disjunctive cuts corresponding to the polyhedra in L , for every polyhedron P . Our results imply interesting consequences, related to split rank and to integral lattice-free polyhedra, that extend recent research findings.

Esra Buyuktahtakin, Wichita State University (with Joseph Hartman, Cole Smith)

Partial objective function inequalities for the multi-item capacitated lot-sizing problem

We study a mixed integer programming model of the multi-item capacitated lot-sizing problem (MCLSP), which incorporates shared capacity on the production of items for each period throughout a planning horizon. We derive valid bounds on the partial objective function of the MCLSP formulation by solving the first t -periods of the problem over a subset of all items, using dynamic programming and integer programming techniques. We then develop algorithms for strengthening these valid inequalities by lifting and back-lifting binary and continuous variables. These inequalities can be utilized in a cutting-plane strategy, in which we perturb the partial objective function coefficients to identify violated inequalities to the MCLSP polytope. We test the effectiveness of the proposed valid inequalities on randomly generated instances.

Robert Hildebrand, University of California, Davis (with Amitabh Basu, Matthias Koeppel)

The triangle closure is a polyhedron

Recently, cutting planes derived from maximal lattice-free convex sets have been studied intensively by the integer programming community. An important question in this research area has been to decide whether the closures associated with certain families of lattice-free sets are polyhedra. For a long time, the only result known was the celebrated theorem of Cook, Kannan and Schrijver who showed that the split closure is a polyhedron. Although some fairly general results were obtained by Andersen, Louveaux and Weismantel "An analysis of mixed integer linear sets based on lattice point free convex sets" (2010), some basic questions have remained unresolved. For example, maximal lattice-free triangles are the natural family to study beyond the family of splits and it has been a standing open problem to decide whether the triangle closure is a polyhedron. We resolve this question by showing that the triangle closure is indeed a polyhedron, and its number of facets can be bounded by a polynomial in the size of the input data.

Life sciences & healthcare

Fri.2.MA 376

Cell biology

Organizer/Chair Stefan Canzar, Johns Hopkins University · Invited Session

Xin Gao, King Abdullah University of Science and Technology (KAUST)

Towards automatic NMR protein structure determination

Protein three-dimensional structure determination is the key towards the understanding of protein functions. Nuclear magnetic resonance (NMR) is one of the two main methods for protein structure determination. Current processes are time consuming and heavily depend on expert knowledge. If we could fully automate this process, this would significantly speedup the structural biology research. In this talk, we will identify the key obstacles in this process and propose solutions by computational methods. We developed peak picking methods based on signal processing techniques, a resonance assignment method based on optimization techniques, and a structure calculation method based on machine learning techniques. Each of these methods subtly handles the noise and imperfection of the others and significantly outperforms the state-of-the-art approaches. Our final system has succeeded in determining high resolution protein structures from a small set of NMR spectra, in a day.

Julian Mestre, University of Sydney (with Stefan Canzar, Khaled Elbassioni, Gunnar Klau)

Tree-constrained matching

We study a generalization of maximum weight bipartite matching, where we are given in addition trees over each side of the bipartition and we add the additional requirement that the matched vertices on each side are not comparable under the ancestor-descendant relation. The

problem arises in the interpretation of live cell video data. We give approximation algorithms and hardness for the problem.

Our algorithm is based on the fractional local ratio technique. In order to obtain a good approximation ratio we uncover and exploit properties of the extreme points of a linear program formulation for our problem.

Sandro Andreotti, FU Berlin (with Gunnar Klau, Knut Reinert)

De novo peptide sequencing with mathematical programming

Peptide sequencing from mass spectrometry data is a key step in proteome research. Especially de novo sequencing, the identification of a peptide from its spectrum alone, is still a challenging problem. We developed a fast and flexible algorithm based on mathematical programming. It builds on the widely used spectrum graph model and can be combined with a variety of scoring schemes. In the graph theoretical formulation the problem corresponds to the longest antisymmetric path problem in a directed acyclic graph. Other algorithms like PepNovo or NovoHMM can solve this problem only for the special case where conflicting node-pairs are non-interleaving. We combine Lagrangian relaxation with an adaptation of Yen's k-shortest paths algorithm to compute suboptimal solutions. This approach shows a significant improvement in running time compared to mixed integer optimization approach with previous solutions being cut off using additional constraints and performs at the same speed like existing de novo sequencing tools. Further we implement a generic probabilistic scoring scheme that can be trained for a dataset of annotated spectra and is independent of the mass spectrometer type.

Logistics, traffic, and transportation

Fri.2.H 0106

Revenue management applications

Organizer/Chair Paat Rusmevichientong, University of Southern California - Invited Session

Srikanth Jagabathula, NYU Stern School of Business (with Vivek Farias, Devavrat Shah)

Assortment optimization under general choice

We consider the problem of static assortment optimization, where the goal is to find the assortment of size at most C that maximizes revenues. This is a fundamental decision problem in the area of Operations Management. It has been shown that this problem is provably hard for most of the important families of parametric of choice models, except the multinomial logit (MNL) model. In addition, most of the approximation schemes proposed in the literature are tailored to a specific parametric structure. We deviate from this and propose a general algorithm to find the optimal assortment assuming access to only a subroutine that gives revenue predictions; this means that the algorithm can be applied with any choice model. We prove that when the underlying choice model is the MNL model, our algorithm can find the optimal assortment efficiently. We also perform an extensive numerical studies to establish the accuracy of the algorithm under more complex choice models like the mixture of MNL models.

Arnoud den Boer, Centrum Wiskunde & Informatica (with Bert Zwart)

Simultaneously learning and optimizing in dynamic pricing and revenue management

'Dynamic pricing' refers to practices where the selling price of a product is not a fixed quantity, but can easily be adjusted over time and adapted to changing circumstances. In an online sales channel, the availability of digital sales data enables firms to continuously learn about consumer behavior, and optimize pricing decisions accordingly. As a result, estimation and optimization can be considered simultaneously; the problem then is not only to optimize profit, but also to optimize the 'learning process'. A key question in these problems is whether a learning-by-doing approach - always choosing the optimal price w.r.t. current estimates - has a good performance, or whether the decision maker should actively experiment in order to improve his/her knowledge on consumer behavior.

We show that when finite inventory is sold during finite selling seasons, learning-by-doing performs well, and give a bound on the regret (which quantifies the costs for learning). In contrast, in a setting with no inventory restrictions, active experimentation is necessary for optimal learning. We offer an explanation why in these two models, the cost-of-learning behaves differently.

James Davis, Cornell ORIE (with Guillermo Gallego, Huseyin Topaloglu)

Assortment optimization under variants of the nested logit model

We study a class of assortment optimization problems where customers choose among the offered products according to the nested logit model. There is a fixed revenue associated with each product. The objective is to find an assortment of products to offer that maximizes the expected revenue per customer. There are several variants of the nested logit model and the tractability of the optimization problem depends on

which variant is used. The problem is solvable when the range of the nest dissimilarity parameters are between zero and one, and nests do not contain a no purchase option. By removing either of these restrictions the problem becomes NP-hard. However, in these other variants we are able to develop algorithms with desirable worst-case performance guarantees. Of particular note is a data independent approximation algorithm when the nest dissimilarity parameters are restricted to be between zero and one. The algorithms we propose across all variants perform well in computational experiments, generating solutions within a fraction of a percent of optimal.

Logistics, traffic, and transportation

Fri.2.MA 042

Optimization in logistics

Chair Julia Funke, Inform GmbH

Markus Frey, Technische Universität München (with Christian Artigues, Rainer Kolisch)

Column generation for planning the outbound baggage handling at airports

At airports, incoming bags are directed via the baggage handling system to handling facilities, where ground handlers load incoming bags into containers. We present a mixed-integer program scheduling flights' handling period and assigning them to handling facilities. The objective is to minimize the maximal workload of all handling facilities. As the problem exhibits great symmetry, leading to high computation times for branch-and-bound algorithms, the problem is decomposed in several subproblems, reducing symmetry effects. The problem is solved by means of column generation. To further reduce the solution space, dominance criteria are applied.

Armin Fügenschuh, Zuse Institute Berlin (with George Nemhauser, Yulian Zeng)

Scheduling and routing of fly-in safari airplanes

The scheduling and routing of small planes for fly-in safaris is a challenging planning problem. Given a fleet of planes and a set of flight requests with bounds on the earliest departure and latest arrival times, the planes must be scheduled and routed so that all demands are satisfied. Capacity restrictions on the loads and fuel also must be satisfied. Moreover the refueling of the planes, which can only be done in certain locations, must be scheduled. We present a mixed-integer linear programming based formulation for this problem. For its solution we develop a primal heuristic based on randomized local search. Using a branch-and-cut solver, the MILP formulation can be solved to proven optimality only for small instances. To achieve better dual bounds we present a set-covering based reformulation, where new columns are generated on demand by heuristics and exact methods. We also present a reformulation where the time windows are relaxed, and later reintroduced by cutting planes and branching. Numerical results on real-world instances show the computational merits of our approaches.

Julia Funke, Inform GmbH

A mixed integer program for a variant of the truck and trailer routing problem with time windows

The formal problem we consider comes from a logistic yard background. Containers are located in a yard and have to be moved at certain times, e.g., from a storage area to a production line and then later back to a pick-up area or to an external site. For these operations a pool of truck units and special trailers is available. The tasks should be fulfilled within certain time windows at the least possible cost.

Our approach is to define this problem as a mixed integer program and solve it with the MIP-solver SCIP. We define two networks one for truck flows and one for trailer flows. We couple the shared decisions so that the optimization model persists of one problem.

Mixed-integer nonlinear programming

Fri.2.MA 041

Applications of MINLP II

Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen - Invited Session

Wei Huang, TU Munich (with Harald Held, Raymond Hemmecke)

Primal heuristics for nonconvex MINLPs modelling optimal operation of water distribution networks

A water distribution network is a system containing engineered hydraulic components to provide water supply to consumers. The main task in operating a water distribution network is to choose between different sources of water and determine a configuration of pumps and valves to satisfy reliable customer demands. The cost of water, energy, and the number of pump switches should be minimized. We present a detailed mixed integer nonlinear programming (MINLP) model involving nonconvex constraints and objective.

Due to the difficulty of solving these problems directly, most approaches in the literature focus on approximations or relaxations. In our research we aim at solving them to global optimality. The solver used in the computational test implements a spatial branch and bound algorithm to find global optimality for factorable MINLPs.

Concerning nonconvexities and integralities as well as the size of networks and time horizon, the general-purpose solver cannot find a primal solution within 24 hours. In this talk, we present several primal heuristics creating fully feasible solutions.

Harald Held, Siemens AG

Challenges and requirements for MINLPs in industrial applications

Practitioners often face the question how to operate, e.g., a plant, a network, or a manufacturing process. In many cases, modeling this as a mathematical optimization problem supports the operator to find a good, ideally best, operating decision. Since there are many well developed mixed-integer linear programming (MILP) solvers, this is what has so far typically been used to provide an operator with good decisions in reasonable time.

However, in many industrial applications, describing a system's physical behavior involves non-linear functions. In these cases, simplification to an MILP could mean a significant loss of accuracy, and a mixed-integer non-linear programming (MINLP) model would be more appropriate. Thanks to recent algorithmic advances and software implementations, the integration of MINLP models into industrial applications has become more viable, yet some challenges remain.

In this talk, we give a few examples of industrial applications where MINLPs can be employed, and demonstrate some challenges and requirements to gain an operator's acceptance.

Multi-objective optimization

Fri.2.H 1029

Portfolio selection

Chair Carlos Abad, Columbia University

Carlos Abad, Columbia University (with Garud Iyengar)

Portfolio selection with multiple spectral risk constraints

We propose an iterative algorithm to efficiently solve the portfolio selection with multiple spectral risk constraints. Since the conditional value at risk (CVaR) is a special case of the spectral risk function, our algorithm solves portfolio selection problems with multiple CVaR constraints. In each step, the algorithm solves a very simple separable convex quadratic program. The algorithm extends to the case where the objective is a utility function with mean return and a weighted combination of a set of spectral risk constraints, or maximum of a set of spectral risk functions. We report numerical results that show that our proposed algorithm is very efficient, and is at least two orders of magnitude faster than the state of the art general purpose solver for all practical instances.

Nonlinear programming

Fri.2.H 0107

Stability and solution methods

Organizer/Chair Diethard Klatte, University of Zurich · Invited Session

Diethard Klatte, University of Zurich (with Bernd Kummer)

Metric regularity versus strong regularity for critical points of nonlinear programs

In this talk, we study perturbed nonlinear optimization problems in a setting which includes standard nonlinear programs as well as cone constrained programs. We discuss conditions for metric regularity of the critical point system, or, equivalently, for the Aubin property of the critical point map. Our focus is on conditions under which the critical point map has the Aubin property if and only if it is locally single-valued and Lipschitz, or, equivalently, metric regularity and strong regularity coincide. In particular, we show that constraint nondegeneracy and hence uniqueness of the multiplier is necessary for the Aubin property of the critical point map.

Stephan Büttikofer, Institute of Data Analysis and Process Design, Zurich University of Applied Sciences (with Diethard Klatte)

Influence of inexact solutions in a lower level problem on the convergence behavior of a nonsmooth newton method

In recent works of the authors a nonsmooth Newton was developed in an abstract framework and applied to certain finite dimensional optimization problems with $C^{1,1}$ data. The $C^{1,1}$ structure stems from the presence of an optimal value function of a lower level problem in the objective or the constraints. Such problems arise, for example, in

semi-infinite programs under a reduction approach without strict complementarity and in generalized Nash equilibrium models. Using results from parametric optimization and variational analysis, the authors worked out in detail the concrete Newton schemes for these applications and discussed wide numerical results for (generalized) semi-infinite problems. This Newton scheme requests the exact computation of stationary points of a lower level problem, which is problematic from a numerical point of view. In this talk we discuss the influence of inexact stationary points on the feasibility and the convergence properties of the Newton scheme. We will make use of a perturbed Newton scheme and give concrete estimates of the convergence radius resp. rate for the perturbed scheme.

Bernd Kummer, HU Berlin

Newton schemes for functions and multifunctions

To solve an inclusion 0 in $H(x)$ we consider iterations of the type 0 in $F(x_{k+1}, x_k)$ in Euclidean spaces. To ensure convergence, the approximations between H and F play the crucial role and will be discussed. We present situations where the auxiliary problems require to study eps-subdifferentials or proximal point steps. Additionally, we consider the case when H is a continuous or only locally Lipschitz function f , and F represents inclusions 0 in $f(x_k) + Gf(x_k)(x_{k+1} - x_k)$ with some generalized derivative Gf . Then the iterations describe certain standard and non-standard nonsmooth Newton methods with more or less strong convergence conditions.

Nonlinear programming

Fri.2.H 0112

Optimality conditions I

Chair Andrei Dmitruk, Russian Academy of Sciences

Feyzullah Ahmetoğlu, Giresun University

Necessary conditions for a convex programming problem in Banach spaces partially ordered by a cone with empty interior

The existence of saddle point of the Lagrange function for a convex programming problem in Banach spaces ordered by a cone with empty interior is established under a strong simultaneity of condition. As a consequence the Kuhn-Tucker conditions are derived. It is shown that the Slater and the strong simultaneity conditions are equivalent if the cone determining the partial order has an interior.

Kalpna Shukla, Banaras Hindu University, Varanasi, India (with Shashi Mishra)

Global parametric sufficient optimality conditions for semi-infinite discrete minimax fractional programming involving generalized V - ρ -invex functions

In this paper, we have considered semi-infinite discrete minimax fractional programming problems

$$\text{Minimize } \max_{1 \leq i \leq p} \frac{f_i(x)}{g_i(x)} \quad (P)$$

$$\text{Subject to } G_j(x, t) \leq 0, \forall t \in T_j, \quad j \in \underline{q},$$

$$H_k(x, s) = 0, \forall s \in S_k, \quad k \in \underline{r}, \\ x \in X,$$

where p, q and r are positive integers, X is an open convex subset of \mathbb{R}^n (n -dimensional Euclidean space), for each $j \in \underline{q} \equiv \{1, \dots, q\}$ and $k \in \underline{r}, T_j$ and S_k , are compact subset of complete metric spaces, for each $i \in \underline{p}, f_i$ and g_i are real-valued functions defined on X , for each $j \in \underline{q}, z \rightarrow G_j(z, t)$ is a real-valued function defined on X for all $t \in T_j$, for each $k \in \underline{r}, z \rightarrow H_k(z, s)$ is a real-valued function defined on X for all $s \in S_k$ for each ...

Andrei Dmitruk, Russian Academy of Sciences (with Nikolai Osmolovskii)

Conditions for a weak minimality in optimal control problems with integral equations of Volterra type

On a time interval $[0, T]$ consider the problem:

$$x(t) = x(0) + \int_0^t f(t, s, x(s), u(s)) ds,$$

$\eta_j(p) = 0, \quad j = 1, \dots, m, \quad \varphi_i(p) \leq 0, \quad i = 1, \dots, \nu, \quad J = \varphi_0(p) \rightarrow \min$, where $p = (x(0), x(T)), x \in \mathbb{R}^n, u \in \mathbb{R}^m$.

Theorem 1 (First order necessary conditions). Let a process $\hat{w} = (\hat{x}(t), \hat{u}(t))$ provide a weak minimum. Then $\exists (\alpha_0, \dots, \alpha_\nu) \geq$

0, $(\beta_1, \dots, \beta_m)$ not all zero, and n -vector function $\psi(t)$ satisfying the conditions:

$$\begin{aligned}\dot{\psi}(s) &= \int_s^T \dot{\psi}(t) f_x(t, s, \hat{x}(s), \hat{u}(s)) dt - \psi(T) f_x(T, s, \hat{x}(s), \hat{u}(s)), \\ \int_s^T \dot{\psi}(t) f_u(t, s, \hat{x}(s), \hat{u}(s)) dt - \psi(T) f_u(T, s, \hat{x}(s), \hat{u}(s)) &= 0, \\ \psi(0) &= l_{x_0}, \quad \psi(T) = -l_{x_T},\end{aligned}$$

where

$$l(p) = \sum_i \alpha_i \varphi_i(p) + \sum_j \beta_j \eta_j(p).$$

We also give second order necessary and sufficient conditions.

Nonlinear programming

Fri.2.MA 004

Fast gradient methods for nonlinear optimization and applications I

Organizer/Chair William Hager, University of Florida · Invited Session

Zhang Hongchao, Louisiana State University (with William Hager)

An adaptive preconditioned nonlinear conjugate gradient method with limited memory

An adaptive preconditioner is developed for the conjugate gradient method based on a limited memory BFGS matrix. The preconditioner is only used when the iterates lie in an ill-conditioned subspace, otherwise, the usual conjugate gradient algorithm is applied. The resulting algorithm uses less memory and has lower computational complexity than the standard L-BFGS algorithm, but performs significantly better than either the conjugate gradient method or the L-BFGS quasi-Newton method for the CUTer test problems.

Rui Diao, Institute of Computational Mathematics and Scientific/Engineering Computing, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (with Yu-Hong Dai, Xin-Wei Liu)

A sequential quadratic programming method without a penalty function or a filter for general nonlinear constrained optimization

We present a primal-dual interior-point method without using a penalty function or a filter for solving the constrained optimization with general equality and inequality constraints. The method combines the interior-point approach with a sequential quadratic programming without using a penalty function or a filter. The algorithm is terminated with an approximate KKT point or is stopped with a singular stationary point or an infeasible stationary point. We adopt several numerical techniques for solving subproblems and updating strategy to ensure our algorithm suitable for large scale problems. The numerical experiments with CUTer collection show that the algorithm is efficient.

Gerardo Toraldo, University of Naples Federico II (with Roberta de Asmundis, Daniela di Serafino)

On the use of spectral properties of the steepest descent method

In the last two decades the innovative approach of Barzilai and Borwein (BB) has stimulated the design of faster gradient methods for function minimization, which have shown to be effective in applications such as image restoration. The surprising behaviour of these methods has been only partially justified, mostly in terms of the spectrum of the Hessian matrix. On the other hand the well known ability of the Cauchy Steepest Descent (SD) to reveal second order information about the problem has been little exploited to modify the method in order to design more effective gradient methods. In this work we show that, for convex quadratic problems, second order information provided by SD can be exploited to improve the usually poor practical behaviour of this method, achieving computational results comparable with those of BB, with the further advantage of monotonic behaviour. Our analysis also provides insight into the relaxed gradient method by Raydan and Svaiter.

Nonsmooth optimization

Fri.2.H 1012

Nonsmooth optimization and applications

Organizer/Chair Dominikus Noll, Université de Toulouse · Invited Session

Dominikus Noll, Université de Toulouse

Non-convex bundle algorithm with inexact sub-gradient and function values

We discuss a non-convex bundle method where function values and subgradients are available only up to an error ϵ , which remains unknown to the user. We show that even in that situation one can still assure (under practical hypotheses) that every accumulation point x^* of the sequence x^j of serious iterates is approximate critical in the sense that

$$0 \in \partial f(x^*) + \delta(\epsilon)B,$$

where B is the unit ball, and where the final precision $\delta(\epsilon)$ depends on the error precision ϵ of function and subgradient values. In the realm of convex bundling results of this flavor have been pioneered by Hintermüller and Kiwiel. The principal new difficulty in non-convex bundling it to provide a substrate for the convex cutting plane mechanism, and this problem was solved by the author for a large class of problems including all instances of practical interest. Here we discuss the more specific case of *downshifted tangents*, an oracle which we used successfully in a variety of applications in automatic control.

Frank Fischer, Chemnitz University of Technology (with Christoph Helmlberg)

An asynchronous parallel bundle method for Lagrangian relaxation

Lagrangian relaxation is frequently used for decomposing discrete optimization problems and the standard parallel approach would solve the subproblems in parallel. Here we propose a different approach that optimizes, asynchronously in parallel, subspaces of multipliers that are selected dynamically. The algorithm starts several parallel processes and in a kind of parallel coordinated descent each process selects a subspace with large predicted decrease. Then each process optimizes the associated multipliers independently until a certain improvement level has been achieved and writes its solution back to the global data. Because this improvement may lead to increased violation of other constraints, the algorithm automatically detects and tracks these dependencies and respects them in future subspace selections ensuring global convergence. Preliminary computational results show that the presented approach may be turned into a viable alternative for applications of practical relevance.

Optimization in energy systems

Fri.2.MA 549

Congestion management and pricing

Organizer/Chair Mette Bjørndal, NHH Norwegian School of Economics · Invited Session

Endre Bjørndal, NHH (with Mette Bjørndal, Victoria Gribkovskaia)

Congestion management in the nordic electricity market

Presently in the Nordic day-ahead market, zonal pricing or market splitting is used for congestions between a predetermined set of price areas. Intra-zonal congestion is resolved by counter trading or redispatching in the regulation market. We study aggregation choices when simplifying nodal prices into zonal or area prices. We discuss two different aggregation concepts, which we call economic and physical aggregation, and their relation to optimal nodal prices. In a model of the Nordic electricity market we consider an hourly case from winter 2010 and present analyses of the effects of different congestion management methods on prices, quantities, surpluses and network utilization.

Linda Rud, NHH Norwegian School of Economics (with Mette Bjørndal, Endre Bjørndal)

Nodal versus zonal pricing: Market power in day-ahead versus in balancing services

Presently in the Nordic day-ahead market, zonal pricing or market splitting is used for congestions between a predetermined set of price areas. Intra-zonal congestion is resolved by counter trading or redispatching based on bids from the regulation power market. In a stylized model, we compare this joint model of handling congestions to the theoretically correct method of nodal pricing. Furthermore, we investigate the implications of both schemes for exercising market power in congested network scenarios.

Yves Smeers, Université Catholique de Louvain (with Danny Rath)

Stochastic equilibrium in investment models: Capacity expansion in the power

An investor in power generation assets faces unprecedented uncertainty on the evolution of the sector. The market equilibrium is hence one under uncertainty. Agents can be risk neutral or risk averse. We therefore insert risk functions in order to account for idiosyncratic risk (risk that is not priced by the CAPM) in investments. Adding a risk function on the cost in a standard (stochastic) capacity expansion planning model can be done and we retain a convex program but it poses questions on the interpretation. We structure the discussion the interpretation around market completeness. In a world of perfect risk trading we can derive a price vector for all instruments from a system risk function. The complete market can be represented in terms of stochastic programming. The assumption of perfect risk trading is however rather heroic for investments that last 20 to 30 years. We hence relax the assumption of perfect risk trading and allow for different stochastic discount factors. The interpretation becomes more difficult since the incomplete market is no longer amenable to a stochastic programming approach.

Optimization in energy systems

Fri.2.MA 550

Generation and expansion problems

Chair Roman Cada, University of West Bohemia

Michael Lindahl, Technical University of Denmark (with Niels-Christian Fink Bagger)

Discrete optimization support system for the collection grid in large offshore wind parks

Offshore wind parks have in the recent years started to grow significantly in size making the task of deciding on how to build the cable collection grid a lot more complex. The goal is to connect all turbines down to a substation by using different types of cables. The objective is then to minimize the cost by minimizing the amount of cables, connections and loss of power. The project is made in collaboration with DONG Energy which is market leader in building offshore wind parks. A mathematical representation of the problem is given which is turned into a MIP model by linear approximations of the quadratic power losses. It is shown how the problem is simplified by removing uninteresting connections. In order to solve the problem within a reasonable time the local branching framework is used. The considered test case is the Anholt Project which is a large offshore wind park including 111 wind turbines and 1 substation. It is shown how this can be used, not only to reduce cost, but also to easily explore different scenarios and see how the solution is affected if different constraints are added or other properties are changed.

Stefano Zigrino, University of Bergamo (with Marida Bertocchi, Laureano Escudero, Maria Teresa Vespucci)

A multistage stochastic model for the electric power generation capacity expansion problem of a price-taker power producer in a multi-year horizon

We consider the optimal electric power generation capacity expansion problem over a multi-year time horizon of a price-taker power producer, who has to choose among different production technologies, while taking into account regulatory constraints on CO₂ emissions, incentives to generation from renewable energy sources and risk due to uncertainties of prices and of market share. A multi-stage stochastic MILP model is developed for determining the evolution of the generation system along the time horizon, with the aim of maximizing the expected total profit, subject to a set of constraints to be satisfied for each scenario. Additionally, the maximization of the expected profit is subject, alternatively, to first-order stochastic dominance constraints (sdc), for a set of profiles given by pairs of threshold profit values and probability of not reaching them, and to second-order sdc, whose set of profiles is given by pairs of threshold profit values and bounds on the expected shortfalls on reaching the thresholds. Provisional results are reported of a computational comparison between the following strategies: parameters' expected value, risk neutral and first- and second-order sdc.

Roman Cada, University of West Bohemia

Optimizing nuclear fuel reload patterns

A nuclear reactor operates in cycles. At the end of every cycle a fraction of spent fuel assemblies is to be replaced by fresh ones. A new collection of fuel assemblies is to be distributed in the reactor core. It is necessary to meet all safety criteria and also minimize costs and maximize production of electrical energy.

We present several possible mathematical models which are suitable for attacking the problem. In general it is a multicriteria nonlinear combinatorial optimization problem. We will also discuss a problem of multicycle optimization in which several consecutive fuel cycles are to be optimized. Finally we present results obtained by the Athena code developed for VVER type reactors (but the use of it is not limited to them).

PDE-constrained opt. & multi-level/multi-grid meth.

Fri.2.H 0111

PDE-constrained optimization problems with non-smooth structures

Chair Caroline Löbhard, Humboldt-Universität zu Berlin

Duy Luong, Imperial College London (with Panos Parpas, Daniel Rueckert, Berc Rustem)

A multiresolution algorithm for large scale non-smooth convex optimization problems

We develop an algorithm based on multigrid concepts and apply it to nondifferentiable convex optimization problems. The approach utilizes the first order method and a hierarchy of models of different fidelity. The goal is to exploit the efficiency of the lower resolution model and propagate the information of the solution to the high resolution model. We discuss the convergence of the algorithm and show numerical re-

sults in a Computer Vision application. The convergence results apply to a broad class of non-smooth convex optimization problems.

Michelle Vallejos, University of the Philippines

Multigrid methods for elliptic optimal control problems with pointwise mixed control-state constraints

Elliptic optimal control problems with pointwise mixed control-state constraints are considered. To solve the problem numerically, multigrid techniques are implemented. The numerical performance and efficiency of the multigrid strategies are discussed and interpreted in comparison with other existing numerical methods.

Caroline Löbhard, Humboldt-Universität zu Berlin (with Michael Hintermüller, Ronald Hoppe)

Optimal control of elliptic variational inequalities: A mesh-adaptive finite element solver

A wide range of optimization problems arise originally in a non-discrete function space setting which has to be discretized in order to find an approximate solution. It is the idea behind mesh-adaption techniques, to find a discrete space that fits best to the unknown continuous solution. While adaptive methods are well-established in solvers for partial differential equations, only a few work has been done for optimal control problems.

We consider the optimal control of an elliptic variational inequality, a problem class with a challenging analytic and algorithmic background on the one hand, and a wide range of applications on the other hand. Moving on the border line between numerical analysis and computational optimization, we show the principle of goal oriented error estimation operating with the C-stationarity system in the continuous as well as the discrete setting, present a numerical solver for the mathematical program with equilibrium constraints (MPEC) and analyze the benefit of our adaptive solver compared to a method working on a uniformly refined mesh.

PDE-constrained opt. & multi-level/multi-grid meth.

Fri.2.MA 415

Hierarchical methods for the design of nanoporous materials

Organizer/Chair Robert Lewis, College of William and Mary - Invited Session

Paul Boggs, Sandia National Laboratories (with Julien Cortial, David Gay, Michael Lewis, Kevin Long, Stephen Nash)

Combining multi-grid and domain decomposition as preconditioners for a class of multi-level PDE-constrained optimization problems

Recently we developed a multi-grid optimization (MG/Opt) strategy for solving a class of multi-level, multi-physics problems that arise in the design of nanoporous materials. The method works well on moderate-sized problems, but it is clear that additional strategies would be required for the large problems of interest. In this talk, we discuss our use of domain decomposition (DD) to extend our MG/Opt work to larger problems. In particular, we adopt the point of view that DD and MG/Opt are both preconditioning strategies and we demonstrate an effective combination of MG/Opt and DD to solve these much larger problems. Numerical results will be presented.

David Gay, AMPL Optimization, Inc. (with Paul Boggs, Stewart Griffiths, Robert Lewis, Kevin Long, Stephen Nash, Robert Nilson)

Optimization algorithms for hierarchical problems, with application to nanoporous materials

This talk concerns optimization algorithms for designing complex hierarchical systems, motivated by applications to the design of nanoporous materials. Such materials have a broad range of engineering applications, including gas storage and filtration, electrical energy storage in batteries and capacitors, and catalysis. The design of these materials involves modeling the material over many length scales, leading to a hierarchy of mathematical models. Our algorithms are also hierarchical in structure, with the goal of exploiting the model hierarchy to obtain solutions more rapidly. We discuss implementation issues and present some computational results.

Robert Lewis, College of William and Mary (with Stephen Nash)

Using inexact gradients in a multilevel optimization algorithm

Optimization algorithms typically require gradients of the objective and constraints; however, computing accurate gradients can be computationally expensive. We discuss the implications of using inexact gradients in the context of the multilevel optimization algorithm MG/Opt. MG/Opt recursively uses a hierarchy of models, of less fidelity but also less cost, to obtain search directions for finer-level models. However, MG/Opt requires the gradient on the fine level in order to define the recursion. We discuss the impact of gradient errors on the multilevel recursion in MG/Opt under various assumptions about the source of the error in the gradients. We illustrate these impacts both analytically and numerically for a number of model problems.

Sparse optimization & compressed sensing

Fri.2.H 1028

Structured matrix optimization

Organizer/Chair Inderjit Dhillon, UT Austin · Invited Session

Ewout van den Berg, Stanford University (with Emmanuel Candes)

Phase-retrieval using explicit low-rank matrix factorization

Recently, Candes et al. proposed a novel methodology for phase retrieval from magnitude information by formulating it as a matrix-completion problem. In this work we develop an algorithm aimed at solving large-scale instances of this problem. We take advantage of the fact that the desired solution is of rank one and use low-rank matrix factorization techniques to attain considerable speed-up over existing approaches. We consider phase recovery in both the noisy and noiseless setting and study how various design choices affect the performance and reliability of the algorithm.

Zaid Harchaoui, INRIA (with Miroslav Dudik, Jérôme Malick)

Lifted coordinate descent for learning with Gauge regularization

We study learning problems with general sparsity-inducing matrix regularization penalties. We formulate the matrix regularizers as Gauge functions, and, using their structure, we lift the optimization problem in a higher space where we propose to apply a coordinate descent algorithm. Our framework allows to efficiently tackle difficult matrix-regularized objectives, e.g., with a trace-norm, or a group trace-norm, regularization penalty. We present experimental results on synthetic datasets and on real-world large-scale computer vision datasets. Our algorithm is competitive and often outperforms existing approaches on large-scale problems.

Inderjit Dhillon, UT Austin (with Cho-Jui Hsieh, Pradeep Ravikumar, Matyas Sustik)

Sparse inverse covariance matrix estimation using quadratic approximation

The L1-regularized Gaussian maximum likelihood estimator has been shown to have strong statistical guarantees in recovering a sparse inverse covariance matrix, or alternatively the underlying graph structure of a Gaussian Markov Random Field, from very limited samples. We propose a new algorithm for solving the resulting optimization problem which is a regularized log-determinant program. In contrast to other state-of-the-art methods that largely use first order gradient information, our algorithm is based on Newton's method and employs a quadratic approximation, but with some modifications that leverage the structure of the sparse Gaussian MLE problem. We present experimental results using synthetic and real application data that demonstrate the considerable improvements in performance of our method when compared to other state-of-the-art methods.

Stochastic optimization

Fri.2.MA 141

Target oriented optimization under uncertainty

Organizer/Chair Melvyn Sim, NUS Business School · Invited Session

Zhuoyu Long, National University of Singapore (with Lucy Gongtao Chen, Melvyn Sim)

Managing operational and financing decisions to meet consumption targets

We study dynamic operational decision problems where risky cash flows are resolved over a finite planning horizon. Financing decisions via lending and borrowing are available to smooth out consumptions over time with the goal of achieving prescribed consumption targets. Our target-oriented decision criterion has salient properties of subadditivity, convexity and respecting second-order stochastic dominance. We show that if borrowing and lending are unrestricted, the optimal policy is to finance consumptions at the target levels for all periods except the last. Moreover, the optimal policy has the same control state as the optimal risk neutral policy and could be achieved with relatively modest computational effort. Under restricted financing, the optimal policies correspond to those that maximize expected additive-exponential utilities, and can be obtained by an efficient algorithm. We also analyze the optimal policies of joint inventory-pricing decision problems under the target-oriented criterion and provide optimal policy structures. With a numerical study, we report favorable computational results for using targets in regulating uncertain consumptions over time.

Melvyn Sim, NUS Business School (with Shao-Wei Lam, Tsan Sheng Ng, Jin-Hwa Song)

Multiple objective satisficing under uncertainty

We propose a class of functions, called multiple objective satisficing (MOS) criteria, for evaluating the level of compliance of a set of objectives in meeting their targets collectively under uncertainty. The MOS criteria include the targets' achievement probability (success probability criterion) as a special case and also extend to situations when the probability distribution is not fully characterized. We focus on a class of

MOS criteria that favors diversification, which has the potential to mitigate severe shortfalls in scenarios when an objective fails to achieve its target.

Jin Qi, National University of Singapore (with Patrick Jaillet, Melvyn Sim)

Routing optimization with deadlines under uncertainty

We study a routing problem with deadlines imposed at a given subset of nodes, and uncertain arc travel times characterized by distributional information set. Our model is static in the sense that the routing decision is made prior to the realization of uncertain travel times. To find an optimal routing policy such that arrival times at the nodes "effectively" respect deadlines, we first introduce a new measure named Lateness Index to evaluate the performance of meeting deadlines. It is defined as the minimum risk tolerance parameter such that its worst-case certainty equivalent arrival time is no larger than the deadline presumed at the corresponding node. Instead of specifying the exact probability distribution of the uncertain arc travel time, we assume its true distribution lies in a family of distributions, which is characterized by some descriptive statistics. We show that some special cases of our problem, such as when only one node has a deadline requirement, are polynomially solvable. And for the general case, we can develop computationally more "efficient" algorithms to find exact optimal routing policy by only solving a series of deterministic routing problems.

Stochastic optimization

Fri.2.MA 144

Stochastic algorithms

Chair Nikolaus Hansen, INRIA, Research Centre Saclay, University Paris-Sud

Song Luo, University of Tsukuba (with Maiko Shigeno, Mingchao Zhang)

A nonadaptive probabilistic group testing algorithm for detecting consecutive positives of linear DNA library

Identifying and isolating clones containing a particular segment of a specific DNA sequence of interest play important roles in molecular biology. Group testing is one of useful techniques to reduce the number of nonadaptive tests and screening necessary for determining which clones contain the segment. A testing algorithm is proposed for a case where clones are placed in a linear order corresponding to their appearance in the linear DNA and where the DNA library is constructed by consecutive clones. The proposed algorithm, which is based on a computationally feasible stochastic model of consecutive positive clones, efficiently identifies the consecutive positives of a linear DNA library.

Nikolaus Hansen, INRIA, Research Centre Saclay, University Paris-Sud (with Anne Auger, Yann Ollivier)

Information-geometric optimization

Given an arbitrary search space with an arbitrary objective function and a parametrized family of probability distributions on this search space, we derive in a generic way a stochastic search method. The derivation is based on invariance principles, keeping the number of arbitrary decisions to a minimum. If the parametrization of the probability distribution is a smooth manifold, we derive a canonical ODE and the related IGO flow that conducts a natural gradient ascent on the manifold. The ascent is based on a time-dependent transformation of the original objective function. Via discretization, a corresponding search algorithm can be derived. Depending on the given family of probability distributions, several well-known algorithms are recovered.

Madeleine Theile, TU Berlin (with Timo Kötzing, Dirk Sudholt)

How crossover helps in pseudo-boolean optimization

Understanding the impact of crossover on performance is a major problem in the theory of genetic algorithms (GAs). In this talk I present new insights on working principles of crossover by analyzing the performance of crossover-based GAs on the simple functions OneMax and Jump. First, the potential speedup by crossover is assessed when combined with a fitness-invariant bit shuffling operator that simulates a lineage of independent evolution on a function of unitation. Theoretical and empirical results show drastic speedups for both functions. Second, a simple GA without shuffling is considered and the interplay of mutation and crossover on Jump is investigated. If the crossover probability is small, subsequent mutations create sufficient diversity, even for very small populations. Contrarily, with high crossover probabilities crossover tends to lose diversity more quickly than mutation can create it. This has a drastic impact on the performance on Jump. The theoretical findings are complemented by Monte Carlo simulations on the population diversity.

Telecommunications & networks

Fri.2.H 3002

Game theoretic concepts in telecommunications

Chair Fabian Medel, Universidad de Chile

Fabian Medel, Universidad de Chile (with Alejandro Jofré)

Optimal regulation with non discriminatory prices in mobile two way access, with call externalities and heterogeneous costumers

The existence of collusion and exclusion in mobile markets, coupled with increased supply in the range of services to the costumers, has led regulators to confront a difficult problem in the search for tools to promote competition in this market. In this sense, there was an oligopolistic market model with multiple wireless services, different types of users and the presence of a market regulator. The models used is nonlinear market equilibrium in the subgame perfect equilibria among firms (MPEC). Strategic behavior of firms contemplates Nash equilibria and predatory interactions, encompassing most models existing in the literature. The result was a detailed analysis of regulatory actions of the non-discriminatory call prices of the firms and the impact on social welfare. Obtaining the optimal strategy by the regulator would be through a substantial reduction of access charges, even below the marginal cost of service, facilitating the entry of new competitors by a fair use of the infrastructure of third parties.

Jonatan Krolkowski, Zuse Institute Berlin (ZIB) (with Anastasios Giovanidis, Tobias Harks)

Game theoretic model for the downlink in cellular mobile networks: Nash equilibria and algorithmic convergence

In the downlink of multicell wireless networks, a number of mobile stations (MSs) should be assigned to a set of spatially distinct base stations (BSs). Two questions are addressed in our work: Which MS is served by which BS, and how much power it consumes. The aim is to provide sufficient Signal-to-Interference-Noise-Ratios (SINR) with constraints on the power emissions per BS.

A central optimization of these parameters is costly. To this aim we propose a decentralized algorithm based on game theory, whose outcome is a pure-strategy Nash equilibrium (PNE).

The MSs aim at non-cooperatively optimizing their payoff functions. All information necessary to each MS is its channel quality from all the BSs and the current strategy choices of the other MSs.

This problem is more involved than already investigated models of uplink communication scenarios. We show that a PNE cannot be ensured even in small cases, when considering interference between all pairs of BSs and MSs. Simplification leads to versions of the problem as congestion games with player specific payoff functions, thereby showing the existence of PNEs.

Telecommunications & networks

Fri.2.H 3503

Markovian and randomized techniques for network optimization

Chair Olivier Fercoq, INRIA Saclay and CMAP École Polytechnique

Olivier Fercoq, INRIA Saclay and CMAP École Polytechnique (with Marianne Akian, Mustapha Bouhtou, Stéphane Gaubert)

Polyhedral and ergodic control approaches to PageRank optimization and spam detection

We study the PageRank optimization problem, which consists in finding an optimal outlink strategy for a web site. In each page, some hyperlinks are controlled while the others are not. We show that the problem can be modeled by a Markov decision process with ergodic reward, in which the webmaster determines the transition probabilities of web surfers. Although the number of actions may be exponential, we show that an associated polytope of transition measures has a concise representation, from which we deduce that the problem is solvable in polynomial time. Then we give an alternative application of PageRank optimization with the search engine's point of view: link spam detection and demotion. From seeds of hand-picked trusted and spam pages, we define a PageRank optimization problem where the cost function penalizes known spam pages and hyperlink removals. The invariant measure, called MaxRank, is interpreted as a modified PageRank vector, used to rank web pages. We show that the bias vector of the associated ergodic control problem is a measure of the "spaminess" of each page. We introduce scalable algorithms that allowed us to perform numerical experiments on large size datasets.

Arthur Gómez, University of Vale do Rio dos Sinos (with Carlos Weissheimer, Junior)

Development of a hybrid algorithm based on the application of metaheuristics on an Internet Protocol Television platform using Tabu Search (TS) and Genetic Algorithm (GA)

The technology internet protocol television (IPTV) is a strong factor impacting on society. She has been exploited, by different means of

transmission, for multimedia content delivery service based on internet protocol (IP). Currently, IPTV is the subject of several studies, and it can bring many benefits to society such as support for interactivity and increased interoperability in home networks. This paper presents the development and implementation of a hybrid algorithm based on the application of metaheuristics on an IPTV platform using tabu search (TS) and genetic algorithm (GA). This algorithm makes it possible analysis and study of the following parameters: baud rate, audio quality, number of costumers and bandwidth. The focus is find the best parameters setting for the transmission given the characteristics of the IPTV client. After validation of the algorithm were performed experiments that help understand the dynamics of the system and enable find a good solution that can be simulated by the network simulator 3 (NS3).

Cristobal Guzman, Georgia Institute of Technology (with Roberto Cominetti)

Network congestion control with Markovian multipath routing

In this paper we consider an integrated model for TCP/IP protocols with multipath routing. The model combines a network utility maximization for rate control based on end-to-end queuing delays, with a Markovian traffic equilibrium for routing based on total expected delays. We prove the existence of a unique equilibrium state which is characterized as the solution of an unconstrained strictly convex program. A distributed algorithm for solving this optimization problem is proposed, with a brief discussion of how it can be implemented by adapting the current Internet protocols.

Variational analysis

Fri.2.H 2035

Optimization in infinite dimensional spaces

Organizer/Chair Alexander Zaslavski, The Technion - Israel Institute of Technology · Invited Session

Joël Blot, Université Paris 1 Panthéon-Sorbonne

Discrete-time Pontryagin principles and ordered Banach spaces

We provide new Pontryagin principles in infinite horizon and discrete time for systems governed by a difference inequality, $x_{t+1} \leq f_t(x_t, u_t)$, where the order is defined by a cone in an infinite-dimensional Banach space. To obtain our results, we use a method of reduction to finite horizon, and special properties of ordered Banach spaces.

Tzanko Donchev, University of Architecture and Civil Engineering (with Robert Bair, Qamar Din)

Runge-Kutta methods for differential equations with variable time of impulses

In the paper Runge-Kutta methods of order p are used to approximate the solutions of differential equations with variable times of impulses in general form. We prove that under natural assumption these methods have order of approximation $O(h^p)$. Illustrative examples are provided. Several strategies to find the jump point of the approximate solution for order two and four Runge-Kutta methods are tested. The models studied can be applied in some control problems of population dynamics and mathematical economics.

Elena Resmerita, Alpen-Adria University (with Klaus Frick, Dirk Lorenz)

A discrepancy principle for the augmented Lagrangian method

The augmented Lagrangian method received much attention recently (also under the name Bregman iteration), as an approach for regularizing inverse problems. This work shows convergence and convergence rates for this method when a special a posteriori rule, namely Morozov's discrepancy principle, is chosen as a stopping criterion. As potential fields of application we study implications of these results for particular examples in imaging, that is total variation regularization as well as ℓ^q penalties with $q \in [1, 2]$.

Variational analysis

Fri.2.H 2051

Duality in convex optimization

Organizer/Chair Radu Ioan Bot, Chemnitz University of Technology · Invited Session

Ernö Csetnek, Chemnitz University of Technology (with Radu Bot)

Conjugate duality and the control of linear discrete systems

We consider a constrained minimization problem, the function to be minimized being a convex one with values in the extended real line, and the set of constraints is governed by a set valued operator with convex graph. We attach a dual problem to it and we deliver regularity conditions guaranteeing the equality of the optimal objective values of the two problems and we discuss also the existence of optimal solutions. The results are applied to the control of linear discrete systems.

André Heinrich, Chemnitz University of Technology (with Radu I. Bot, Gert Wanka)

The support vector machines approach via Fenchel-type duality

Supervised learning methods are powerful techniques to learn a

function from a given set of labeled data, the so-called training data. In this talk the support vector machines approach for classification and regression is investigated under a theoretical point of view that makes use of convex analysis and Fenchel duality. Starting with the corresponding Tikhonov regularization problem, reformulated as a convex optimization problem, we introduce a conjugate dual problem to it and prove that, whenever strong duality holds, the function to be learned can be expressed via the optimal solutions of the dual problem. Corresponding dual problems are then derived for different loss functions for the classification task as well as for the regression task. The theoretical results are applied by numerically solving an image classification task originating from a quality control problem a supplier of the automotive industry was faced with. The accuracy of the resulting classifiers demonstrate the excellent performance of support vector classification based on this high dimensional real-world data.

Sorin-Mihai Grad, Chemnitz University of Technology (with Radu Ioan Bot, Gert Wanka)

Classical linear vector optimization duality revisited

We introduce a vector dual problem that successfully cures the trouble encountered by some classical vector duals to the classical linear vector optimization problem in finite-dimensional spaces. This new-old vector dual is based on a vector dual introduced by Bot and Wanka for the case when the image space of the objective function of the primal problem is partially ordered by the corresponding nonnegative orthant, extending it for the framework where an arbitrary nontrivial pointed convex cone partially orders the mentioned space. The vector dual problem we propose has, different to other recent contributions to the field which are of set-valued nature, a vector objective function. Weak, strong and converse duality for this vector dual problem are delivered and it is compared with other vector duals considered in the same framework in the literature. We also extend a well-known classical result by showing that the efficient solutions of the classical linear vector optimization problem coincide with its properly efficient solutions (in any sense) when the image space is partially ordered by a nontrivial pointed closed convex cone.

Approximation & online algorithms

Fri.3.H.3010

Routing and shortest paths

Organizer/Chair Nicole Megow, Technische Universität Berlin · Invited Session

Vincenzo Bonifaci, IASI-CNR, Italy (with Varma Girish, Kurt Mehlhorn)

Physarum can compute shortest paths

Physarum Polycephalum is a slime mold that apparently is able to solve shortest path problems. A mathematical model has been proposed by biologists to describe the feedback mechanism used by the slime mold to adapt its tubular channels while foraging two food sources s_0 and s_1 . We prove that, under this model, the mass of the mold will eventually converge to the shortest s_0 - s_1 path of the network that the mold lies on, independently of the structure of the network or of the initial mass distribution.

This matches the experimental observations by the biologists and can be seen as an example of a "natural algorithm", that is, an algorithm developed by evolution over millions of years.

Jannik Matuschke, TU Berlin (with Tobias Harks, Felix König)

Approximation algorithms for capacitated location routing

Location routing integrates the two classical optimization problems of facility location and vehicle routing, addressing both location decisions and tour planning in a single step. Given a graph whose vertex set consists of facilities and clients with given demands, the problem is to find a subset of facilities that have to be opened, and a set of tours originating from those facilities, serving all clients while at the same time respecting the (uniform) capacity limitation of the vehicles in use, and minimizing the incurred opening and connection costs.

We derive the first polynomial time constant factor approximation for capacitated location routing and some variants of the problem, including cross-docking, prize-collecting, and a group variant. Our results originate from combining algorithms and lower bounds for different relaxations of the original problem.

Finally, we present a computational study on popular benchmark instances from the literature and newly generated large-scale random instances. It turns out that, in practice, solutions of our algorithm are much closer to optimality than guaranteed by the theoretical approximation factor.

René Sitters, VU University, Amsterdam

Metric service systems and the generalized work function algorithm

There are some very intriguing open problems in online optimization. Examples are the k -server conjecture (deterministic and random-

ized) and the dynamic search tree conjecture (dynamic optimality conjecture). Both problems are in the class of metrical service systems (online shortest path problems). It is widely believed that dynamic search trees are constant competitive. We show some strong techniques for proving constant competitiveness of metrical service systems and develop a universal theory of competitive analysis of metrical service systems. In particular, we apply this to the generalized 2-server problem and show that the generalized work function algorithm is constant competitive in any metric space, as was conjectured by Koutsoupias and Taylor (2004).

Combinatorial optimization

Fri.3.H.3004

Packing, covering and domination II

Organizer/Chair Annegret Wagler, University Blaise Pascal (Clermont-Ferrand II)/CNRS · Invited Session

Arnaud Pecher, University of Bordeaux (with Christine Bachoc, Alain Thiery)

On the theta number of powers of cycle graphs

A main result of combinatorial optimization is that clique and chromatic number of a perfect graph are computable in polynomial time (Grötschel, Lovász and Schrijver 1981).

We give a closed formula for Lovász's theta number of the powers of cycle graphs C_k^{d-1} and of their complements, the circular complete graphs $K_{k/d}$. As a consequence, we establish that the circular-chromatic number of a circular-perfect graph is computable in polynomial time, which extends the above result from the chromatic number to the circular-chromatic number, and from perfect graphs to the superclass of circular-perfect graphs.

Silvia Bianchi, Universidad Nacional de Rosario (with Mariana Escalante, Maria Montelar)

The disjunctive rank of the stable set polytope of web graphs

We consider the behavior of the disjunctive operator defined by Balas, Ceria and Cornuéjols, over the clique relaxation of the stable set problem on webs. The disjunctive rank of a graph is the minimum number of steps of this procedure needed to obtain the convex hull of integer solutions in it. In this work we obtain the disjunctive rank of all webs, when starting from the clique relaxation. We find that almost every web W_n^k attain the upper bound of its disjunctive rank, i.e. k , except for those of the form W_{3k+r}^k with $r = 0$ or $r = 1$, that requires $k - 2$ or $k - 1$ steps, respectively. Our results allow us to obtain bounds for the disjunctive rank of a larger class of graphs such as quasi-line graphs and their complements, the near-bipartite graphs.

Luis Torres, Escuela Politécnica Nacional (with Paola Tolomei)

On the Chvátal-closure of the fractional set covering polyhedron of circulant matrices

The set covering polyhedron $Q^*(C_n^k)$ related to circulant 0,1-matrices has been the object of several recent studies. It has been conjectured that the Chvátal-rank of its fractional relaxation $Q(C_n^k)$ is equal to 1. In 2009, Argiroffo and Bianchi characterized all vertices of $Q(C_n^k)$. Building upon their characterization, we investigate the first Chvátal-closure of this polyhedron. Our aim is to obtain a complete linear description, by considering the integral generating sets of the cones spanned by the normal vectors of the facets containing each vertex of $Q(C_n^k)$. In this talk we present the results obtained so far for some classes of vertices. In particular, our construction yields a counterexample to a conjecture that all facets of $Q^*(C_n^k)$ are given by boolean, nonnegative, and so-called minor inequalities having only coefficients in $\{1, 2\}$. At the same time, we motivate why a weaker version of this conjecture might still hold.

Combinatorial optimization

Fri.3.H.3005

Nonlinear combinatorial optimization problems II

Organizer/Chair Christoph Buchheim, TU Dortmund · Invited Session

Franklin Djeumou Fomeni, Lancaster University (with Adam Letchford)

A dynamic programming heuristic for the quadratic knapsack problem

It is well known that the standard (linear) knapsack problem can be solved exactly by dynamic programming in pseudo-polynomial time. The quadratic knapsack problem, by contrast, is NP-hard in the strong sense, which makes it unlikely that it can be solved in pseudo-polynomial time. It is possible, however, to convert the dynamic programming approach to the linear knapsack problem into a heuristic for

the quadratic version. We explain how this can be done, and present some extremely promising computational results.

Ruth Hübner, Georg-August-Universität Göttingen (with Christoph Buchheim, Anita Schöbel)
Ellipsoid bounds for convex quadratic integer programming

Solving unrestricted convex quadratic integer programs by a branch&bound approach requires lower bounds on the objective value. We are going to follow the approach by Buchheim, Caprara and Lodi [2011] and approximate the quadratic function by an "easier" quadratic function which underestimates the original one. Geometrically, we approximate the level set of the objective by an auxiliary ellipsoid for which we require that the corresponding quadratic integer problem can be solved by rounding its continuous optimal solution. In a first approach we are going to restrict the choice of the auxiliary ellipsoid to axis-parallel ellipsoids (corresponding to the level sets of separable convex quadratic functions). Which one is the "best" auxiliary axis-parallel ellipsoid depends not only on the given objective function but also on the respective continuous optimal solution which changes in every node of the branching tree. As it is expensive to find a good auxiliary ellipsoid we want to decide on a single ellipsoid and use it for the whole algorithm. This raises the question on how to compare different ellipsoids. To this end, worst-case and average-case arguments are discussed.

Sourour Elloumi, ENSIE

A unified view of linear and quadratic convex reformulation for binary quadratic programming

We consider binary quadratic programs (QP) having a quadratic objective function, linear constraints, and binary variables. Many classical solution methods of these problems are based on exact reformulation of QP into an equivalent mixed integer linear program. Several linearization methods were studied in the literature. More recent solution methods also build an exact reformulation but into a problem which objective function is quadratic and convex. A common point of the two approaches is that the continuous relaxation of the reformulated problem is a convex optimization problem that can be solved in polynomial time. This makes it possible to use a general branch-and-bound framework to solve the reformulated problem and even to rely on the strongness of standard solvers. In this paper, we show that several quadratic convex reformulation methods, as well as classical linearization, can be viewed within a unified framework. This shows the non-surprising result that linearization is a particular quadratic convex reformulation on the one hand. On the other hand, it allows to compare these methods from a theoretical point of view.

Combinatorial optimization

Fri.3.H 3008

Faster algorithms for network flow problems

Organizer/Chair James Orlin, MIT · Invited Session

James Orlin, MIT

Max flows in $O(nm)$ time and sometimes less

We present improved polynomial time algorithms for the maximum flow problem defined on a network with n nodes and m arcs. King, Rao, and Tarjan [1992] solved the max flow problem in $O(nm + n^{1+\epsilon})$ time. They subsequently improved the running time to $O(nm \log_{m/(n \log n)} n)$. We establish that the max flow problem is solvable in $O(nm)$ time for all n and m . Moreover, in the case that $m = O(n)$, we improve the running time to $O(n^2 / \log n)$. Further improvements are possible if the number of arcs with finite capacity is $O(n)$ or if $\log U^* < n^{1/3-\epsilon}$.

Yahav Nussbaum, Tel Aviv University (with Glencora Borradaile, Philip Klein, Shay Mozes, Christian Wulff-Nilsen)

Multiple-source multiple-sink maximum flow in directed planar graphs in near-linear time

We consider the problem of finding a maximum flow from a set of source nodes to a set of sink nodes in an n -node directed planar graph with arc capacities. The multiple-source multiple-sink maximum flow problem can be solved using a standard single-source single-sink maximum flow algorithm, as there is a simple reduction which connects a single super-source to the set of sources and the set of sinks to a single super-sink. However, this reduction does not preserve the planarity of the graph, and we have to use a maximum flow algorithm for general (non-planar) graphs in conjunction with the reduction, which requires $O(n^2 \log n)$ time. We present an $O(n \log^3 n)$ algorithm for the problem. This is the first algorithm for the problem that exploits the planarity of the graph to get a faster time bound. Our algorithm combines wide range of techniques, including pseudoflows, flow partitioning scheme, the duality between flow circulation and shortest paths in planar graphs, succinct representation of a flow in a planar graph, and

other planarity-exploiting algorithms. This work was presented at FOCS 2011.

László Végh, London School of Economics

Concave generalized flows with applications to market equilibria

We consider a nonlinear extension of the generalized network flow model, with the flow leaving an arc being an increasing concave function of the flow entering it, as proposed by Truemper and Shigeno. We give a polynomial time combinatorial algorithm for solving corresponding flow maximization problems, finding an ϵ -approximate solution in $O(m(m + \log n) \log(MUm/\epsilon))$ arithmetic operations and value oracle queries, where M and U are upper bounds on simple parameters. This also gives a new algorithm for linear generalized flows, an efficient, purely scaling variant of the Fat-Path algorithm by Goldberg, Plotkin and Tardos, not using any cycle cancellations.

We show that this general convex programming model serves as a common framework for several market equilibrium problems, including the linear Fisher market model and its various extensions. Our result immediately extends these market models to more general settings. We also obtain a combinatorial algorithm for nonsymmetric Arrow-Debreu Nash bargaining, settling an open question by Vazirani.

Combinatorial optimization

Fri.3.H 3012

Graph optimization problems in the streaming model

Organizer/Chair Anand Srivastav, Christian Albrechts Universität zu Kiel · Invited Session

Christian Konrad, LIAFA – Université Paris Diderot (Paris 7)

On the order of graph streams

While classical graph algorithms assume random access to the input graph, a semi-streaming algorithm receives a sequence of edges of the input graph and processes them one-by-one in sequential order while using small memory. How important is the order in which the edges arrive? Are there problems that become easier if we assume that edges arrive in uniform random order instead of worst-case order? Are there other particular orders that make sense to consider? We address these questions via two concrete examples: the unweighted bipartite graph matching problem and the unweighted semi-matching problem: given a bipartite graph (A, B, E) , in the semi-matching problem we aim to match all A vertices to B vertices such that the maximal degree of the B vertices is minimized. The talk concludes with a review on open problems in this area of research.

Lasse Kliemann, Christian-Albrechts-Universität zu Kiel (with Sebastian Eggert, Peter Munstermann, Anand Srivastav)

$(1 + 1/k)$ -Approximate maximum matching in bipartite graph streams in $O(k^5)$ passes and improvements

Two algorithms for the *maximum matching* problem in *bipartite graph streams* will be presented. RAM is restricted to $O(n)$ edges at a time, n denoting the number of vertices. Given a parameter k , we find a $(1 + 1/k)$ approximation. The *number of passes* is allowed to depend on k . When the number of passes is independent of n , we speak of a *semi-streaming algorithm*.

The first algorithm is a semi-streaming algorithm requiring only $O(k^5)$ passes. It was developed and analyzed purely theoretically. The second algorithm was developed by means of Algorithm Engineering. It was proven to have the same approximation guarantee as the first one – but in the worst case it can require a linear (in n) number of passes. Hence it is no semi-streaming algorithm. However, on a large set of test instances it outperformed the first algorithm by an impressive margin: for a 90% approximation ($k = 9$) the second algorithm never required more than 94 passes, while the first one required up to 32,000. But even those 32,000 are far away from the theoretical $O(k^5)$ bound.

Mariano Zelke, Goethe-Universität Frankfurt am Main

Algorithmic techniques for data stream computations

For computation on today's massive data, it is not reasonable anymore to assume the existence of a main memory containing the whole input for fast random access. On such data streaming algorithms are appropriate for which fast random access to the input and even its complete storage are dispensable. In contrast, the input is processed in an online fashion using a main memory size that significantly falls below the input data size.

In this talk we present some basic techniques for streaming algorithms which provide the foundation for more elaborate approaches. We illustrate reservoir sampling to draw uniform random samples out of a stream of unknown length and sliding window sampling to exclude outdated input items from the sample. Moreover, we show how to approximate the frequency moments of a stream via the technique of AMS sampling and how to estimate the multiplicity of an item in the input stream by using the count-min sketch.

Combinatorial optimization

Fri.3.H 3013

Flows, cuts, and sparsifiers

Organizer/Chair Lisa Fleischer, Dartmouth College · Invited Session

Nicholas Harvey, University of British Columbia

Graph sparsifiers

A sparsifier of a graph is a sparse, weighted subgraph for which every cut has approximately the same value as the original graph, up to a factor of $1 \pm \epsilon$. Sparsifiers were first studied by Benczur and Karger (1996). They have wide-ranging applications, including fast network flow algorithms, fast linear system solvers, etc.

We describe a new approach to constructing sparsifiers: by sampling each edge uv with probability inversely proportional to the edge-connectivity between u and v . This results in a sparsifier with $O(n \log^2(n)/\epsilon^2)$ edges, answering a question of Benczur and Karger. A variant of this argument shows that one can obtain sparsifiers by sampling uniformly random spanning trees. Our proofs are based on extensions of Karger's contraction algorithm which allow it to compute minimum "Steiner" cuts.

Jonathan Kelner, MIT (with Paul Christiano, Aleksander Madry, Gary Miller, Richard Peng, Daniel Spielman, Shanghua Teng)

Electrical flows, linear systems, and faster approximations of maximum flows, minimum s - t cuts, and multicommodity flows in undirected graphs

In this talk, I'll describe a new collection of techniques for approximately solving maximum flow, minimum s - t cut, and multicommodity flow problems in capacitated, undirected graphs. Using these techniques, we obtain asymptotically faster algorithms for all three, breaking running time barriers that have stood for over 30 years.

For graphs with n vertices and m edges, I'll show how to compute ϵ -approximately maximum flows in time $\tilde{O}(m^{4/3})\text{poly}(1/\epsilon)$ and ϵ -approximately minimum s - t cuts in time $\tilde{O}(m + n^{4/3})\text{poly}(1/\epsilon)$. We do this by treating our graph as a network of resistors and solving a sequence of electrical flow problems with varying resistances on the edges. Each of these may be reduced to the solution of a system of linear equations in a Laplacian matrix, which can be solved in nearly-linear time.

I'll then discuss why generalizing this approach to the multicommodity setting requires more general classes of linear systems and iterative methods. Using these, we find ϵ -approximate solutions to the maximum concurrent flow problem with k commodities in time $\tilde{O}(m^{4/3}\text{poly}(k, \epsilon^{-1}))$.

Christophe Weibel, Google Inc. (with Amit Chakraborti, Lisa Fleischer)

When the cut condition is enough: Characterization of multiflow problems by forbidden minors

For a supply graph $G = (V, E)$ and a demand graph $H = (V, F)$, an assignment of capacities to the edges of G and demands to the edges of H is said to satisfy the *cut condition* if for any cut in the graph, the total demand crossing the cut is no more than the total capacity crossing it. The pair (G, H) is called *cut-sufficient* if for any assignment of capacities and demands that satisfy the cut condition, the demands defined on H can be routed within the network with capacities defined on G .

A pair (G, H) is said to contain another pair (G', H') as a minor if it is possible to obtain (G', H') from (G, H) by contracting edges of G and deleting edges of G and H . We propose to characterize cut-sufficient pairs by forbidden minors.

In particular, we prove a previous conjecture giving the minimal set of forbidden minors for instances with a series-parallel supply graph, and propose a conjecture extending our results to planar supply graphs.

Complementarity & variational inequalities

Fri.3.MA 313

Contraction methods for separable convex optimization in the frame of Vis

Organizer/Chair Bingsheng He, Nanjing University · Invited Session

Guoyong Gu, Nanjing University (with Bingsheng He, Xiaoming Yuan)

Customized proximal point algorithms: A unified approach

This talk takes a unified look at the customized applications of proximal point algorithms (PPA) to two classes of problems, namely, the linearly constrained convex problem with a generic or separable objective function and a saddle-point problem. We model these two classes of problems as mixed variational inequalities, and show how PPA with customized proximal parameters can yield favorable algorithms, which are able to exploit the structure of the models. Our customized PPA revisits turns out to be a unified approach in designing a number of efficient algorithms, which are competitive with, or even more efficient than some

benchmark methods in the existing literature such as the augmented Lagrangian method, the alternating direction method and a class of primal-dual methods, etc. From the PPA perspective, the global convergence and the $O(1/t)$ convergence rate are established in a uniform way.

Min Tao, Nanjing University (with Sheng He, Ming Yuan)

A slightly changed alternating direction method of multipliers for separable convex programming

The classical alternating direction method of multipliers (ADMM) has been well studied in the context of linearly constrained convex programming and variational inequalities where the involved operator is formed as the sum of two individual functions without crossed variables. Recently, ADMM has found many novel applications in diversified areas such as image processing and statistics. However, it is still not clear whether ADMM can be extended to the case where the operator is the sum of more than two individual functions. In this paper, we present a ADMM with minor change for solving the linearly constrained separable convex optimization whose involved operator is separable into three individual functions. The $O(1/t)$ convergence rate of the proposed methods is demonstrated.

Xingju Cai, Nanjing University (with Guoyong Gu, Bingsheng He, Xiaoming Yuan)

ADM based customized PPA for separable convex programming

The ADM is classical for solving a linearly constrained separable convex programming problem, and it is well known that ADM is essentially the application of a concrete form of the PPA to the corresponding dual problem. This paper shows that an efficient method competitive to ADM can be easily derived by applying PPA directly to the primal problem. More specifically, if the proximal parameters are chosen judiciously according to the separable structure of the primal problem, the resulting customized PPA takes a similar decomposition algorithmic framework as that of ADM. The customized PPA and ADM are equally effective to exploit the separable structure of the primal problem, equally efficient in numerical senses and equally easy to implement. Moreover, the customized PPA is ready to be accelerated by an over-relaxation step, yielding a relaxed customized PPA for the primal problem. We verify numerically the competitive efficiency of the customized PPA to ADM, and the effectiveness of the over-relaxation step. Furthermore, we provide a simple proof for the $O(1/t)$ convergence rate of the relaxed customized PPA.

Conic programming

Fri.3.H 2036

Algebraic geometry and conic programming III

Organizers/Chairs Markus Schweighofer, Universität Konstanz; Lek-Heng Lim, University of Chicago · Invited Session

Caroline Uhler, IST Austria

Maximum likelihood estimation in Gaussian graphical models from the perspective of convex algebraic geometry

We study multivariate normal models that are described by linear constraints on the inverse of the covariance matrix. Maximum likelihood estimation for such models leads to the problem of maximizing the determinant function over a spectrahedron, and to the problem of characterizing the image of the positive definite cone under an arbitrary linear projection. We examine these problems at the interface of statistics and conic optimization from the perspective of convex algebraic geometry.

Thorsten Theobald, Goethe University Frankfurt am Main (with Kai Kellner, Christian Trabant)

Containment problems for polytopes and spectrahedra

Spectrahedra are the feasible regions of semidefinite programs. In this talk we study the computational question(s) whether a given polytope or spectrahedron S_A (as given by a linear matrix pencil $A(x)$) is contained in another one S_B .

Our results both concern the computational complexity (extending results on the polytope/polytope-case by Gritzmann and Klee) as well as sufficient conditions to certify containment (whose study was initiated by Ben-Tal, Nemirovski and Helton, Klep, McCullough).

Conic programming

Fri.3.H 2038

Algebraic symmetry in semidefinite programming

Organizer/Chair Etienne de Klerk, Tilburg University · Invited Session

Etienne de Klerk, Tilburg University (with Dmitrii Pasechnik)

Improved lower bounds on crossing numbers of graphs via semidefinite programming

The crossing number problem for graphs is to draw a graph in the plane with a minimum number of edge crossings. Crossing numbers

are of interest for graph visualization, VLSI design, quantum dot cellular automata, RNA folding, and other applications. On the other hand, the problem is notoriously difficult. In 1973, Erdős and Guy wrote that: "Almost all questions that one can ask about crossing numbers remain unsolved." For example, the crossing numbers of complete and complete bipartite graphs are still unknown in general. Moreover, even for cubic graphs, it is NP-hard to compute the crossing number. Different types of crossing numbers may be defined by restricting drawings; thus the two-page crossing number corresponds to drawings where all vertices are drawn on a circle, and all edges either inside or outside the circle. In this talk, we will survey some recent results, where improved lower bounds were obtained for (two-page) crossing numbers of complete and complete bipartite graphs via optimization.

Marianna Eisenberg-Nagy, CWI Amsterdam (with Etienne de Klerk, Renata Sotirov, Uwe Truetsch)
Symmetry in RLT cuts for the quadratic assignment and standard quadratic optimization problems

The reformulation-linearization technique (RLT), introduced in [W. P. Adams, H. D. Sherali, A tight linearization and an algorithm for zero-one quadratic programming problems, *Management Science*, 32(10): 1274–1290, 1986], provides a way to compute linear programming bounds on the optimal values of NP-hard combinatorial optimization problems. This type of method has become known as a lift-and-project strategy: the "lifting" refers to the addition of new variables, and the "projection" to projecting the optimal values of the new variables to a feasible point of the original problem.

We study the RLT technique for two specific problems, namely the standard quadratic program and the quadratic assignment problem (QAP). We show how one may solve the second level RLT relaxation with additional semidefinite programming constraints in the presence of suitable algebraic symmetry in the problem data. As a result we are able to compute the best known bounds for certain graph partitioning problems involving strongly regular graphs. These graph partitioning problems have QAP reformulations.

Dion Gijswijt, TU Delft

Symmetric semidefinite programs based on tuples

The independence number in graphs can be bounded using semidefinite programming. Symmetries of the graph can be used to reduce the size of the SDP. A dramatic example of this occurs in coding theory, where the Lovász theta number for exponentially large graphs reduces to a polynomial sized LP (Delsarte bound) by virtue of the large symmetry group of the Hamming space.

Here we discuss stronger bounds, related to the Lasserre hierarchy, that involve tuples of vertices of the graph. We show efficient methods to apply symmetry reduction in this case. An explicit result (joint work with A. Schrijver and H. Mittelmann) gives improved bounds on binary codes using four-tuples, and shows that the quadruply shortened Golay code is optimal.

Derivative-free & simulation-based opt.

Fri.3.H 3003A

Novel applications of derivative-free and simulation-based optimization

Organizers/Chairs Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory
 · Invited Session

Juan Meza, UC Merced

Derivative-free optimization methods for determining the surface structure of nanosystems

Many properties of nanosystems depend on the atomic configuration at the surface. One common technique used for determining this surface structure is based on the low energy electron diffraction (LEED) method, which uses a sophisticated physics model to compute the diffraction spectra. While this approach is highly effective, the computational cost of the simulations can be prohibitive for large systems. Here, we describe the use of pattern search methods and simplified physics surrogates for determining the surface structure of nanosystems. The pattern search methods have the property of being able to handle both continuous and categorical variables. This allows the simultaneous optimization of the atomic coordinates as well as the chemical identity.

Andrew Conn, T. J. Watson Research Center (with Sippe Douma, Lior Horesh, Eduardo Jimenez, Gijs van Essen)

Simulation-based optimization: Integrating seismic and production data in history matching

We present two recent complementary approaches to mitigate the ill-posedness of this problem: Joint inversion – the development of a virtual sensing formulation for efficient and consistent assimilation of 4D time-lapse seismic data; Flow relevant geostatistical sampling – de-

spite conscientious efforts to minimize the undeterminedness of the solution space, through joint inversion or through regularization, the distribution of the unknown parameters conditional on the historical data, often remains illusive. This is typically accounted for through extensive sampling. We propose a reduced space hierarchical clustering of flow-relevant indicators for determining representatives of these samples. This allows us to identifying model characteristics that affect the dynamics. The effectiveness of both methods are demonstrated both with synthetic and real field data. Time permitting we will discuss the ramifications for the optimization and the numerical linear algebra.

Annick Sartenaer, University of Namur (FUNDP) (with Serge Gratton, Patrick Lalouaux)

Derivative-free optimization for large-scale nonlinear data assimilation problems

Data assimilation consists in techniques to combine observations with a numerical prediction model. The goal is to produce the best estimate of the current state of the system. Two different approaches are used in data assimilation algorithms: the sequential one, based on the statistical estimation theory (Kalman filter) and the variational one, based on the optimal control theory. This last approach amounts to solve a very large nonlinear weighted least-squares problem called 4D-Var (four-dimensional variational problem). In both approaches, evaluating derivatives is challenging as one needs to compute the Jacobian of the model operator. The Ensemble Kalman Filter (EnKF) provides a suitable derivative-free alternative for the first approach by using a Monte-Carlo implementation on the Kalman filter equations. However, no derivative-free variant of the variational approach has been proposed so far. In this talk, we present such a variant, based on a technique to build and explore a sequence of appropriate low dimensional subspaces. Numerical illustration is shown on a shallow water data assimilation problem, including a comparison with the Ensemble Kalman Filter approach.

Finance & economics

Fri.3.H 3021

Optimization in financial markets

Organizer/Chair Teemu Pennanen, King's College London · Invited Session

John Schoenmakers, Weierstrass Institute Berlin (with Denis Belomestny, Marcel Ladkau)

Multilevel primal and dual approaches for pricing American options

In this talk we propose two novel simulation based approaches for pricing American options. (I) The first one is in fact a multi level version of the nested Monte Carlo dual algorithm of Andersen and Broadie (2004), whereas the second one (II) is a multi level version of simulation based policy iteration (cf. Kolodko Sch. 2006), hence a primal approach. The multilevel concept is applied to the number of sub-simulations needed for constructing a dual martingale in (I) and for iterating to a new policy in (II). In both cases the overall complexity turns out to be significantly reduced.

Ari-Pekka Perkkiö, Aalto University (with Teemu Pennanen)

Stochastic programs without duality gaps

This talk is on dynamic stochastic optimization problems parameterized by a random variable. Such problems arise in many applications in operations research and mathematical finance. We give sufficient conditions for the existence of solutions and the absence of a duality gap. Our proof uses extended dynamic programming equations, whose validity is established under new relaxed conditions that generalize certain no-arbitrage conditions from mathematical finance.

Dirk Becherer, Humboldt Universität zu Berlin

Optimal sparse portfolios in continuous time

We discuss sparse portfolio optimization in continuous time. Optimization objective is to maximize the classical expected utility, that is the expectation of a concave functional of portfolio gains. Sparse optimization aims to find asset allocations that contain only few assets or that deviate only in few coordinated from a reference benchmark allocation. Results show that optimal sparse portfolios are less sensitive to estimation errors and performance is superior to optimal portfolio without sparsity constraints, when estimation of model parameters is taken into account.

Finance & economics

Fri.3.H 3027

Decision making

Chair Deepak Kumar, Indian School of Business

Marta Villamil, Universidade do vale do Rio dos Sinos (with Luiz Paulo de Oliveira, Bruno Larentis)

Modelling and simulation of social segmentation with individual and competitive parameters

Social influence is the process by which individuals develop real

changes in their feelings and their behavior as a result of interaction with other individuals. When individuals relate to each other, considering a heterogeneous population, behavior patterns allow groups formation. Studies of group behaviors inside a population have applications like preparation to marketing campaign for competitive products, tendencies analysis of electors in political campaigns and to simulate all situations where groups with antagonist ideas compete for new members. This work proposes the use of Lotka-Volterra differential equations to model the segmentation of a population into two groups, each one associated with concepts/choices competitors. In this scope, the coefficients of the Lotka-Volterra equations are defined from the average of the parameters of the individuals which are member of each group. Furthermore the model is dynamic. Model coefficients are updated as groups update their number of members. Individual parameters also continue to change due interactions. With this, the system modeling is replaced by a stochastic component, becoming the linear stability analysis innocuous.

Deepak Kumar, Indian School of Business

Simultaneous optimization problems in gambling strategies

The optimization problem in portfolio management of meeting objectives with maximum probability and/or within minimum time uses continuous time Red & Black gambling strategies for answers to the problem of (a) maximizing probability of reaching a target before hitting a low and (b) minimizing the expected time of reaching a target. The problem of trying to maximize probability of reaching a target before hitting a low when there is some deadline constraint makes the problem altogether different. The aim is to look into the mathematical structure of the problem in optimal control framework, try to have a discrete analogue of it and have a look into the theoretical issues related to such optimization problems.

José Gilberto Hernández Ramírez, Universidad Metropolitana (with María García G., Gilberto Hernández G.)

The amplitude model and regret model in decision making under uncertainty

Upon reinforcing the traditional methods for decisions making under uncertainty, especially Hurwicz and Laplace, the amplitude model (TAM) was created. TAM, among the parameters to choose the best alternative, takes into account the amplitude. Although it is created to reinforce other methods, TAM has taken own life. Besides TAM has extended to decisions making under risk, with the model of amplitude for risk and uncertainty (MARU). Likewise has worked TAM together the regret model (Minimax). The maximum repentance of Minimax has been used as parameter of TAM and the amplitude of the repentance to evaluate Minimax. In this work continues with this search, of there that the objective of the same one is to create a new model, based on the philosophy of the amplitude model, using simultaneously as parameters the amplitude of the payments and the maximum repentance of the same. To reach this objective will be used like methodology the scientific method for research operations. For the illustration and validation of the new model will be contrasted against the traditional methods and other variant of TAM, through problems created especially for it.

Game theory

Fri.3.MA 005

Learning and computation for game-theoretic problems

Organizer/Chair Vinayak Shanbhag, University of Illinois at Urbana-Champaign · Invited Session

W. Ross Morrow, Iowa State University (with Joshua Mineroff, Kate Whitefoot)

Computing equilibria in regulated differentiated product market models

Game theoretic models are applied to study markets for differentiated product such as personal vehicles, consumer electronics, and various food products and services. One of the most important applications concerns the impact of regulatory policy on market behavior. Practical insights from such models rests on the ability to compute equilibria, which in turn requires solving potentially large Mixed Complementarity Problems (MCPs). This seminar discusses several advances in the formulation of such models and the subsequent computation of equilibrium when firms face regulations with non-smooth regulatory costs. Equilibrium prices are modeled with MCPs, while product design decisions are modeled with a Stackelberg-type two-stage game that results in an MPEC/EPEC. One unique feature of these applications is a lack of regularity as prices increase without bound, a consequence of the type of demand model used. We solve this issue by identifying appropriately coercive problem formulations. Computational results ob-

tained with state-of-the-art NLP software (PATH, KNITRO, SNOPT) are provided for fuel economy regulations in the U.S.

Angelia Nedich, UIUC (with Jayash Koshal, Uday Shanbhag)

A gossip algorithm for aggregative games on graphs

We consider a class of games, termed as aggregative games, being played over a distributed multi-agent networked system. In an aggregative game, an agent's objective function is coupled through a function of the aggregate of all agents decisions. Every agent maintains an estimate of the aggregate and agents exchange this information over a connected network. We study the gossip-based distributed algorithm for information exchange and computation of equilibrium decisions of agents over the network. Our primary emphasis is on proving the convergence of the algorithm under an assumption of a diminishing (agent-specific) stepsize sequence. Under standard conditions, we establish the almost-sure convergence of the algorithm to an equilibrium point. Finally, we present numerical results to assess the performance of the gossip algorithm for aggregative games.

Game theory

Fri.3.MA 043

Analysis of equilibria in noncooperative games

Organizer/Chair Marc Uetz, University of Twente · Invited Session

Martin Hoefer, RWTH Aachen University (with Elliot Anshelevich)

Contribution games in networks

Motivated by contribution scenarios in (social) networks, we analyze network contribution games in which each agent in a network has a budget of effort that he can contribute to different collaborative projects or relationships. Depending on the contribution of the involved agents a relationship will flourish or drown, and to measure success we use a reward function for each relationship. Every agent is trying to maximize the reward from all relationships that it is involved in. We consider pairwise equilibria of this game, and characterize the existence, computational complexity, and quality of equilibrium. Our results concern several natural classes of functions such as convex or concave rewards. We also discuss extensions towards altruistic behavior and different local reward sharing rules.

Tobias Harks, Maastricht University (with Max Klimm)

Congestion games with variable demands

We initiate the study of congestion games with variable demands where the (variable) demand has to be assigned to exactly one subset of resources. The players' incentives to use higher demands are stimulated by non-decreasing and concave utility functions. The payoff for a player is defined as the difference between the utility of the demand and the associated cost on the used resources. Although this class of non-cooperative games captures many elements of real-world applications, it has not been studied in this generality, to our knowledge, in the past. We study the fundamental problem of the existence of pure Nash equilibria. As our main result we give a complete characterizations of cost functions that ensure the existence of at least one pure Nash equilibrium.

Jasper de Jong, University of Twente

Decentralized mechanisms for throughput scheduling

Motivated by the organization of decentralized service systems, we study new models for throughput scheduling. In throughput scheduling, we have a set of jobs i with value w_i , processing requirement p_i , and deadline d_i , to be processed non-preemptively on a set of unrelated servers. The goal is to maximize the total value of jobs finished before their deadline. While several approximation algorithms with different performance guarantees exist for this and related models, we are interested in decentralized mechanisms where the servers act selfishly according to some given, simple protocol. We show by simple, combinatorial arguments that, when each server deploys an α -approximation locally, any Nash equilibrium still yields an $(\alpha + 1)$ -approximation with respect to the global optimum. This bound is tight, even in the case of related machines, unit weights and unit processing times. For models with identical machines, the bound can be improved to $\frac{\alpha e}{\sqrt{e-1}}$. Some of our results also extend to online models with corresponding competitive ratios.

Global optimization

Fri.3.H 0110

Structural aspects of global optimization

Organizer/Chair Oliver Stein, Karlsruhe Institute of Technology · Invited Session

Georg Still, University of Twente

Minimization of nonconvex quadratic functions on special feasible sets

We are interested in global minimization of general quadratic functions on a feasible set F . It is well-known that depending on the specific set F the problem is possibly tractable or hard. We are especially interested in the minimization on the unit simplex F . This problem is just the feasibility problem for copositive programming. The latter recently attracted much attention as it appeared that many hard integer problems can be represented exactly by copositive programs.

In our talk we firstly discuss some interesting properties of quadratic functions such as the number of components of the level sets and the number of (global) minimizers. We then consider copositive programming and give some recent results on the structure of this problem.

Tomas Bajbar, Karlsruhe Institute of Technology

Nonsmooth versions of Sard's theorem

We present a comparison between some versions of Sard's Theorem which have been proven recently for special function classes with different definitions of critical points. The motivation for calling a given point a critical point of a function varies. Considering the class of C^k functions, the class of min-type functions or min-max functions, the motivation for the definition of critical point is the topological structure of the inverse image. Considering the class of set-valued definable mappings, the motivation for the definition of critical points is the property of metric regularity. We compare topological critical points and critical points defined via metric regularity in the class of min-type and min-max functions. We illustrate the whole problematic by some examples.

Dominik Dorsch, RWTH Aachen University (with Hubertus Th. Jongen, Vladimir Shikhman)

Local models in equilibrium optimization

We study equilibrium optimization from a structural point of view. For that, we consider equilibrium optimization problems up to the smooth coordinate transformations locally at their solutions. The latter equivalence relation induces classes of equilibrium optimization problems. We focus on the stable classes corresponding to a dense set of data functions. We prove that these classes are unique and call them "basic classes". Their representatives in the simplest form are called local models. For particular realizations of equilibrium optimization problems basic classes and their local models are elaborated. The latter include bilevel optimization, general semi-infinite programming and Nash optimization.

Global optimization

Fri.3.H 2053

Advances in global optimization VI

Chair Daniel Aloise, Universidade Federal do Rio Grande do Norte

Holger Diedam, Otto-von-Guericke-Universität Magdeburg (with Sebastian Sager)

Global optimal control using direct multiple shooting

Motivated by state-of-the-art algorithms for mixed integer optimal control problems (MIOCP), where lower bounds on the solution are necessary, we developed a numerical method to combine direct multiple shooting with convex relaxation techniques for optimal control problems.

Embedded into an extended branch and bound framework and applied to a MIOCP with relaxed integer decisions, the lower bounds on the solutions allow to determine if the objective value of the resulting optimal control problem is, at least up to a desired epsilon accuracy, close to the global solution. Afterwards, we apply integer approximation methods like the Sum Up Rounding strategy to the relaxed solution in order to obtain arbitrarily close approximations of the global integer solution for a wide range of MIOCPs.

Finally, we present first numerical results on selected benchmark problems from the literature and new challenging problems including mixed integer decisions with relaxed problems that exhibit multiple local minima.

Daniel Aloise, Universidade Federal do Rio Grande do Norte (with Pierre Hansen, Caroline Rocha)

A column generation algorithm for semi-supervised clustering

Clustering is a powerful tool for automated analysis of data. It addresses the following problem: given a set of entities find subsets, called clusters, which are homogeneous and/or well separated. In addition to the entities themselves, in many applications, information is also available regarding their relations in the space. This work presents a column

generation algorithm for minimum sum-of-squares clustering in the presence of must-link and cannot-link pairwise constraints. The computational results show that the proposed algorithm is faster than the current state-of-the-art method.

Implementations & software

Fri.3.H 1058

Parallel optimization software

Organizer/Chair Jeff Linderoth, University of Wisconsin-Madison · Invited Session

Katsuki Fujisawa, Chuo University (with Toshio Endo, Satoshi Matsuoka, Hitoshi Sato, Makoto Yamashita)

High-performance general solver for extremely large-scale semidefinite programming problems

Semidefinite Program (SDP) is one of the most important problems in current research areas in optimization problems. It covers a wide range of applications such as combinatorial optimization, control theory, economics, quantum chemistry, sensor network location, data mining, etc. Solving extremely large-scale SDPs has a significant importance for the current and future applications of SDPs. In 1995, Fujisawa et al. started the SDPA Project aimed for solving large-scale SDPs with numerical stability and accuracy. It is one of pioneers' code to solve general SDPs. The SDPARA is a parallel version of the SDPA on multiple processors and distributed memory, which replaces major bottleneck components of the SDPA by their parallel implementation. In particular, it has been successfully applied on quantum chemistry and combinatorial optimization, the SDPARA on a large-scale super computer called TSUBAME 2.0 in Tokyo Institute of Technology has succeeded to solve the largest SDP which has over one million constraints with high accuracy and make a new world record.

Yuji Shinano, Zuse Institute Berlin (with Tobias Achterberg, Timo Berthold, Stefan Heinz, Thorsten Koch, Stefan Vigerske, Michael Winkler)

ParaSCIP and FiberSCIP – Parallel extensions of SCIP

SCIP is a powerful Mixed Integer Linear and Non-Linear Programming (MILP/MINLP) solver. We will present the implementation of two parallel extensions of SCIP. One is ParaSCIP, which is intended to run on a large scale distributed memory computing environment and the other is FiberSCIP, intended to run in shared memory computing environments. ParaSCIP has successfully been run on the HLRN II super-computer utilizing up to 7,168 cores to solve a single difficult MILP. It has also been tested on a Fujitsu PRIMERGY RX200S5 using up to 512 cores. Even though ParaSCIP and FiberSCIP have different capabilities, they are realized using a single software: the Ubiquity Generator (UG) framework. The latest computational results using the both ParaSCIP and FiberSCIP will be presented.

Cynthia Phillips, Sandia National Laboratories (with Jonathan Eckstein, Ojas Parekh, John Siirola, Jean-Paul Watson)

PICO's new hierarchical branch-and-bound system for massively parallel IP

We will discuss the design, implementation, and large-scale parallel computational results for a new capability in the PICO (Parallel Integer and Combinatorial Optimizer) massively-parallel mixed-integer programming solver. We leverage the basic PICO ramp up system for automatic integer program decomposition and carefully manage runtime conditions to effectively run arbitrary black-box IP solvers on massively parallel systems. Our computational results use Sandia National Laboratories' "Red Sky" system, which has more than 20,000 cores.

Integer & mixed-integer programming

Fri.3.H 2013

Symmetry issues in integer programming

Organizer/Chair Volker Kaibel, Otto-von-Guericke Universität Magdeburg · Invited Session

Matteo Fischetti, University of Padova (with Leo Liberti)

Orbital shrinking

Symmetry plays an important role in optimization. The usual approach to cope with symmetry in discrete optimization is to try to eliminate it by introducing artificial symmetry-breaking conditions into the problem, and/or by using an ad-hoc search strategy. In this paper we argue that symmetry is instead a beneficial feature that we should preserve and exploit as much as possible, breaking it only as a last resort. To this end, we outline a new approach, that we call orbital shrinking, where additional integer variables expressing variable sums within each symmetry orbit are introduced and used to encapsulate model symmetry. This leads to a discrete relaxation of the original problem, whose solution yields a bound on its optimal value. Encouraging preliminary

computational experiments on the tightness and solution speed of this relaxation are presented.

Marc Pfetsch, TU Darmstadt (with Thomas Rehn)

A computational comparison of symmetry handling methods in integer programming

During the past years several methods to handle symmetries in integer programs have been introduced. This includes isomorphism pruning by Margot, orbital branching by Ostrowski et al., symmetry breaking constraints by Liberti, etc. In this talk we present a computational comparison of these different approaches in the framework SCIP. We discuss implementation issues like symmetry detection and the detection of interesting subgroups of the symmetry group as well as their exploitation during the solution process. The tests are run on the highly symmetric instances of Margot and on the MIPLIB 2010. We discuss the results of these test runs, which, as can be expected, depend on the instances at hand. We also compare two different ways to detect symmetry via graph isomorphism.

Jim Ostrowski, University of Tennessee (with Jianhui Wang)

Dominance-strengthened symmetry breaking constraints in the unit commitment problem

Adding symmetry-breaking to a highly symmetric instance of a MILP problem can reduce the size of the problem's feasible region considerably. The same can be said for good dominance constraints. In this talk we will examine the impact of using dominance arguments to strengthen symmetry breaking constraints for the Unit Commitment (UC) problem. Symmetry is present in (traditional formulations of) the UC problem when there are several generators of the same type. We show that by adding dominance strengthened cuts, the number of feasible solutions that need to be considered only grows polynomially as the number of generators increases (so long as the number of unique generators is fixed).

Integer & mixed-integer programming

Fri.3.H 2032

Integer points in polytopes II

Organizers/Chairs Michael Joswig, TU Darmstadt; Günter M. Ziegler, FU Berlin · Invited Session

Benjamin Nill, Case Western Reserve University

Recent developments in the geometry of numbers of lattice polytopes

In this talk, I will give an overview about recent results in the geometry of numbers of lattice polytopes. All of these will deal with the question of what we know about lattice polytopes with a certain number of interior lattice points or none at all. I also hope to show how an invariant in Ehrhart theory possibly allows a unifying view on these results.

Andreas Paffenholz, TU Darmstadt (with Barbara Baumeister, Christian Haase, Benjamin Nill)

Permutation polytopes

A permutation polytope is the convex hull of the permutation matrices of a subgroup of S_n . These polytopes are a special class of 0/1-polytopes. A well-known example is the Birkhoff polytope of all doubly-stochastic matrices defined by the symmetric group S_n . This is a well studied polytope. Much less is known about general permutation polytopes. I will shortly discuss basic properties, combinatorial characterizations, lattice properties, and connections between the group and the polytope. A main focus of my presentation will be on recent results for cyclic groups. Their permutation polytopes correspond to marginal polytopes studied in algebraic statistics and optimization. In particular, I will present families of facet defining inequalities.

Alexander Kasprzyk, Imperial College London (with Gabor Hegedus)

Riemannian polytopes

Given a convex lattice polytope P , one can count the number of points in a dilation mP via the Ehrhart polynomial L_P . The roots of L_P (over \mathbb{C}) have recently been the subject of much study, with a particular focus on the distribution of the real parts. In particular, V. Golyshev conjectured, and the authors recently proved, that any smooth polytope of dimension at most five are so-called Riemannian polytopes; this is, the roots of L_P all satisfy $\Re(z) = -1/2$.

I shall discuss some recent results on Riemannian polytopes, with particular emphasis on reflexive polytopes. In particular, I will discuss the distribution of the roots in the case of a reflexive polytope P , and a characterisation of when P is Reimannian.

Integer & mixed-integer programming

Fri.3.H 2033

Decomposition methods and applications

Organizer/Chair Joe Naoum-Sawaya, University of Waterloo · Invited Session

Joe Naoum-Sawaya, University of Waterloo (with Christoph Buchheim)

A Benders decomposition approach for the critical node selection problem

In this presentation, we discuss the critical node selection problem where given an undirected graph the objective is to remove a given number of nodes in order to minimize the pairwise connections. The critical node selection problem has several important applications arising in supply chain, telecommunication, and in healthcare. To solve large scale instances, we consider the integer programming formulation and propose a Benders decomposition algorithm for its solution. The Benders decomposition approach is implemented in a branch-and-cut algorithm. We also discuss alternative quadratic reformulations and derive valid inequalities.

Emre Celebi, Kadir Has University

An approximation algorithm for Benders decomposition of variational inequality problems

In this talk, we examine an approximate solution of the master problem in Benders decomposition method for large-scale equilibrium models formulated as VI problems. We have used exact or approximate analytic center cutting plane method (ACCPM) within the Benders decomposition of VI problems in order to reduce the computational effort. ACCPM allows for adding another cut to the Benders master problem along with the cut obtained from the dual information of the subproblem. This cut can be calculated (or approximated) from the analytic center of the feasible region of the master problem at each iteration of Benders decomposition. This approach may lead to improvements in the speed of the algorithm compared to the original Benders or Dantzig-Wolfe decomposition of VI problems. A realistic electricity market price simulation model is used to test the algorithm and preliminary results are presented.

Kerem Akartunali, The University of Strathclyde (with Vicky Mak-Hau)

Radiation treatment planning for volumetric modulated arc therapy (VMAT): Optimization and heuristics

Volumetric-modulated arc therapy (VMAT) is a recent technological development in the area of cancer radiation treatment, where the aim is the generation of a treatment plan involving decisions of appropriate radiation dosages, angles and collimator shapes. The problem is computationally very challenging, in particular considering additional problem features such as time limitations. In this talk, we will discuss an integer programming formulation for this problem, and improvements on this formulation using some linearization techniques and valid inequalities. We will present some polyhedral results, and also discuss a branching and column generation framework specifically designed for this problem. We will discuss some computational results, as well as possible future extensions.

Life sciences & healthcare

Fri.3.MA 376

Methods from discrete mathematics in systems biology

Organizer/Chair Utz-Uwe Haus, IFOR, ETH Zürich · Invited Session

Stefanie Jegelka, UC Berkeley (with Jeff Bilmes, Hui Lin)

On fast approximate submodular minimization and related problems

Machine learning problems often involve very large data sets. To test algorithms quickly, we aim to extract a suitable subset of a large training corpus. This is a submodular minimization problem, but the size of the data renders current exact methods very impractical. Graph cuts can be an alternative, but may not be able to efficiently represent any submodular function. We therefore approximate the objective function by a sequence of graph-representable functions. This leads to an efficient approximate minimization algorithm. It turns out that the underlying model not only helps represent submodular functions, it also enhances applications of graph cuts in computer vision, representing non-submodular energy functions that improve image segmentation results.

Edward Rouldes, University of Kentucky (with David Weisrock, Ruriko Yoshida)

Non-parametric species delimitation based on branching rates

Many probabilistic tests have been developed to delimit species based on the coalescent model. These computational efforts rely primarily on parametric models that try to account for known variance found in genetic processes. Unfortunately, this variance is difficult to model precisely. Using non-parametric tests, we develop a method to delineate species by estimating the time species change from growth (e.g., Yule models) to a coalescence process without constraining the

processes to a particular model. Using simulated gene trees from a known species tree, we compare our non-parametric method to established parametric methods.

Giovanni Felici, Consiglio Nazionale delle Ricerche (with Emanuel Weitschek)

Logic data mining in the presence of noisy data

In this work we consider a method for the extraction of knowledge from data. The knowledge is represented as disjunctive normal form (DNF) logic formulas that identify with high precision subsets of the training data. The method is mainly designed for classification purposes, but can be profitably deployed for information compression and data analysis in general. It is based on three main steps: discretization, feature selection and formula extraction. For each step, a mathematical optimization problem is formulated and solved with ad hoc algorithmic strategies. The method is designed to perform exact separation of training data, and can thus be exposed to overfitting when a significant amount of noise is present in the available information. We analyze the main problems that arise when this method deals with noisy data and propose extensions to the discretization, feature selection and formula extraction steps; we motivate these extensions from a theoretical standpoint, and show with experimental evidence how they operate to remove the effect of noise on the mining process.

Logistics, traffic, and transportation

Fri.3.H 0106

Inventory routing

Chair Takayuki Shiina, Chiba Institute of Technology

Samira Mirzaei, Amir Kabir University of Technology (Tehran Polytechnic) (with Abbas Seifi)

Inventory routing problem for distribution of perishable goods

This paper presents a mathematical formulation for inventory routing problem (IRP) that is especially designed for allocating stock of perishable goods. It is assumed herein that the age of perishable inventory has negative impact on the demand of end customers and the percentage of the inventory that is not sold is considered as lost sale. The model balances the transportation cost with the holding cost and lost sale. In addition to regular inventory routing constraints, the model considers a linear function defining lost sale in terms of inventory age. The model is solved to optimality for small instances and is used to obtain lower bounds for larger instances. We have also devised a heuristic method to find good solutions for this class of problems that are later improved within a metaheuristic framework. Computational results indicate that for small size problems, the proposed heuristic can find solutions that are on average no farther than 25% away from the optimal solution in a few seconds. The optimality gap found by CPLEX grows exponentially with the problem size while the ones obtained by the proposed heuristic increase linearly.

Takayuki Shiina, Chiba Institute of Technology

Inventory distribution problem under uncertainty

Two different types of transshipment which are called preventive or emergency transshipment, have been studied separately in the inventory distribution problem. The transshipment in inventory distribution system is important to improve customer service and reduce total cost. In this paper, the inventory distribution problem using both transshipments is formulated as the stochastic programming problem in which customer demand is defined as random variable. The algorithm using L -shaped method is developed and the numerical experiments show that the proposed algorithm is quite efficient. Finally, the advantage using both transshipment is shown.

Logistics, traffic, and transportation

Fri.3.MA 042

Applications of supply chain

Chair Yehua Wei, Massachusetts Institute of Technology

Abolfazl Mirzazadeh, Islamic Azad University of Karaj (with I. Sadeghi)

A bi-criteria inventory model under stochastic environment with considering perishable costs

A new multiple objectives inventory model has been presented in this paper to determine the optimal production quantity. The deterioration items have been considered and the systems costs will be change over the time horizon. In the real situation, some but not all customers will wait for backlogged items during a shortage period and therefore, the model incorporates partial backlogging. The demand rate can be a function of inflation and time value of money where the inflation and time horizon i.e., period of business, both are random in nature. The objectives of the problem are: [1] Minimization of the total expected

present value of costs over time horizon (consists of the deterioration cost, production cost, inventory holding cost, backordering cost, lost sale cost and ordering cost) and [2] Decreasing the total quantity of goods in the warehouse over time horizon. The ideal point approach has been proposed to formulate the model. Also, the numerical example has been provided for evaluation and validation of the theoretical results.

Stefan Waldherr, Universität Osnabrück

Two-stage order sequence planning in shelf-board production

In cooperation with a supplier of kitchen elements the production of storage boards is optimized. Because of the problem's high complexity and the frequent changes of the order situation, the time horizon for the order sequence scheduling should cover at most two days. However, to assure the needed raw material in time for production, it is necessary to determine an approximate schedule outside of the two-day time horizon. Therefore we split the production scheduling into two stages: In a first coarse planning stage we relax the problem by dropping some constraints and consider it as a Min Cost Flow Problem to calculate a production time detailed to the day. This forms the basis for planning the pre-production of the needed raw material to assure their availability. In a second fine planning stage the exact sequence scheduling is carried out taking into account both, resource constraints and sequence-dependent setup- and production times.

Yehua Wei, Massachusetts Institute of Technology (with David Simchi-Levi)

Understanding the performance of the long chain and sparse designs in process flexibility

We study the expected sales of sparse flexibility designs, which are modeled by the expected objective value of a stochastic bipartite max-flow problem. In particular, we focus on the long chain design, a design that has been successfully applied by several industries. First, we uncover an interesting property of the long chain, supermodularity. Then, this property is used to show that the performance of the long chain is characterized by the difference between the expected sales of two simpler designs which leads to the optimality of the long chain among 2-flexibility designs. Finally, under IID demand, this characterization gives rise to three developments: (i) an effective algorithm to compute the expected sales of long chains using only matrix multiplications; (ii) a result that the gap between the fill rate of full flexibility and that of the long chain increases with system size, thus implying that the effectiveness of the long chain relative to full flexibility increases as the number of products decreases; (iii) a risk-pooling result implying that the fill rate of a long chain increases with the number of products, but this increase converges to zero exponentially fast.

Mixed-integer nonlinear programming

Fri.3.MA 041

Modelling, reformulation and solution of MINLPs

Organizer/Chair Leo Liberti, École Polytechnique · Invited Session

Marianna de Santis, Istituto di Analisi dei Sistemi ed Informatica (with Stefano Lucidi)

A method for MINLP problems with simple constraints

We are concerned with the problem of minimizing a continuously differentiable function subject to simple constraints on the variables where some of the variables are restricted to take integer values. To tackle the problem we propose an approach based on a minimization of distributed type: an appropriate local search is performed depending on whether the variable is continuous or integer. The continuous local search is based on an active set method that combines ideas from projected and Newton-type algorithms. For the discrete local search a grid search along the discrete variables is performed.

Leo Liberti, École Polytechnique (with Pietro Belotti, Sonia Cafieri, Jon Lee)

On feasibility-based bounds tightening

Mathematical programming problems involving nonconvexities are usually solved to optimality using a spatial branch-and-bound (sBB) algorithm. Algorithmic efficiency depends on many factors, among which the widths of the bounding box for the problem variables at each branch-and-bound node naturally plays a critical role. The practically fastest box-tightening algorithm is known as FBBT (feasibility-based bounds tightening): an iterative procedure to tighten the variable ranges. Depending on the instance, FBBT may not converge finitely to its limit ranges, even in the case of linear constraints. Tolerance-based termination criteria yield finite termination, but not in worst-case polynomial time. We model FBBT by using fixed-point equations in terms of the variable bounding box, and we treat these equations as constraints of an auxiliary mathematical program. We demonstrate that the auxiliary mathematical problem is a linear program, which can of course be

solved in polynomial time. We demonstrate the usefulness of our approach by improving the open-source sBB solver Couenne.

Claudia D'Ambrosio, CNRS Ecole Polytechnique (with Andrea Lodi, Riccardo Rovatti, Martello Silvano)
Optimistic modeling of non-linear optimization problems by mixed-integer linear programming

We present a new piecewise linear approximation of non-linear optimization problems. It can be seen as a variant of classical triangulations that leaves more degrees of freedom to define any point as a convex combination of the samples. For a hyper-rectangular domain $\mathbb{U} \in \mathbb{R}^L$, partitioned into hyper-rectangular subdomains through a grid defined by n_l points on the l -axis ($l = 1, \dots, L$), the number of potential simplexes is $L! \prod_{l=1}^L (n_l - 1)$, and an MILP model incorporating it without complicated encoding strategies must have the same number of additional binary variables. In the proposed approach the choice of the simplexes is optimistically guided by one between two approximating objective functions, and the number of additional binary variables needed by a straightforward implementation drops to only $\sum_{l=1}^L (n_l - 1)$. The method allows the use of recent methods for representing such a partition with a logarithmic number of constraints and binary variables. We show theoretical properties of the approximating functions, and provide computational evidence of the impact of the method when embedded in MILP models.

Multi-objective optimization

Fri.3.H 1029

Optimality conditions in multiobjective optimization

Organizer/Chair Akhtar Khan, Rochester Institute of Technology · Invited Session

Qinghong Zhang, Northern Michigan University (with G. J. Zalmai)

Efficiency conditions for semi-infinite multiobjective optimization problems

In this study, we present a theorem of the alternative concerning an infinite system of equalities and inequalities, and then, utilizing this result and the concepts of Dini and Hadamard directional derivatives and differentials, we establish a set of Karush-Kuhn-Tucker-type necessary efficiency conditions under the generalized Abadie and Guignard constraint qualifications for a semi-infinite multiobjective optimization problem. Furthermore, we briefly discuss the relevance and applicability of the necessary efficiency results to some semi-infinite multiobjective optimization problems, including a nonclassical problem in the calculus of variations with an infinite number of isoperimetric-type equality and inequality constraints, and problems involving support functions, arbitrary norms, and positive semidefinite quadratic forms.

Akhtar Khan, Rochester Institute of Technology

Second-order optimality conditions and sensitivity analysis in set-valued optimization

This talk will focus on new second-order optimality conditions and sensitivity analysis in set-valued optimization problems. Second-order contingent derivatives and second-order asymptotic derivatives will be used to give optimality conditions and sensitivity analysis. Our second-order results recover a number of known first order optimality conditions and results from sensitivity analysis as special cases. Numerous examples will be presented to explain the main ideas.

Baasansuren Jadamba, Rochester Institute of Technology (with Fabio Raciti)

Regularization of stochastic variational inequalities and comparison of an L_p and a sample-path approach for network problems

The talk will focus on some recent results on stochastic variational inequalities by using regularization techniques. We will also present a comparison between our approach to stochastic variational inequalities and another approach used extensively in the literature. Two small scale network equilibrium problems will be discussed in detail to better illustrate the conceptual difference between the two approaches as well as the computational methods.

Nonlinear programming

Fri.3.H 0107

Decomposition and relaxation methods

Chair Oleg Burdakov, Linköping University

Quentin Louveaux, University of Liège (with Bernard Boigelot, Damien Ernst, Raphaël Fonteneau)

Relaxation schemes for the evaluation of a policy in batch mode reinforcement learning

We study the min max optimization problem introduced for computing policies for batch mode reinforcement learning in a deterministic setting. First, we show that this problem is NP-hard. In the two-stage

case, we provide two relaxation schemes. The first relaxation scheme works by dropping some constraints in order to obtain a problem that is solvable in polynomial time. The second relaxation scheme, based on a Lagrangian relaxation where all constraints are dualized, leads to a conic quadratic programming problem. We also theoretically prove and empirically illustrate that both relaxation schemes provide better results than those given previously for the same problem.

Oleg Burdakov, Linköping University (with John Dunn, Mike Kalish)

An approach to solving decomposable optimization problems with coupling constraints

We consider a problem of minimizing $f_1(x) + f_2(y)$ over $x \in X \subseteq \mathbb{R}^n$ and $y \in Y \subseteq \mathbb{R}^m$ subject to a number of extra coupling constraints of the form $g_1(x)g_2(y) \geq 0$. Due to these constraints, the problem may have a large number of local minima. For any feasible combination of signs of $g_1(x)$ and $g_2(y)$, the coupled problem is decomposable, and the resulting two problems are assumed to be easily solved. An approach to solving the coupled problem is presented. We apply it to solving coupled monotonic regression problems arising in experimental psychology.

Nonlinear programming

Fri.3.H 0112

Optimality conditions II

Chair Alexander Strekalovskiy, Institute for System Dynamics & Control Theory, Siberian Branch of Russian Academy of Sciences

Mourad Naffouti, ESSTT Tunisia (with Aderrahman Boukricha, Mabrouk Daldoul)

On the second order optimality conditions for optimization problems with inequality constraints

A nonlinear optimization problem (P) with inequality constraints can be converted into a new optimization problem (PE) with equality constraints only. This is a Valentine method for finite dimensional optimization. We review second order optimality conditions for (PE) in connection with those of (P) and we give some new results.

Alexander Strekalovskiy, Institute for System Dynamics & Control Theory, Siberian Branch of Russian Academy of Sciences

New mathematical tools for new optimization problems

Following new paradigms of J.-S. Pang [Math. Program., Ser.B (2010) 125: 297–323] in mathematical optimization – competition, hierarchy and dynamics – we consider complementarity problems, bimatrix games, bilevel optimization problems etc, which turn out to be optimization problems with hidden nonconvexities. However, classical optimization theory and method do not provide tools to escape stationary (critical, KKT) points produced by local search algorithms. As well-known, the conspicuous limitation of (classical) convex optimization methods applied to nonconvex problems is their ability of being trapped at a local extremum or even a critical point depending on a starting point. So, the nonconvexity, hidden or explicit, claims new mathematical tools allowing to reach a global solution through, say, a number of critical points.

In such a situation we advanced another approach the core of which is composed by global optimality conditions (GOC) for principal classes of d.c. programming problems. Furthermore, several special local search methods (SLSM) have been developed. Such an approach shows itself really efficient and allows to apply suitable package as X-Press, CPLEX etc.

Nonlinear programming

Fri.3.MA 004

Fast gradient methods for nonlinear optimization and applications II

Organizer/Chair William Hager, University of Florida · Invited Session

Ya-Feng Liu, Chinese Academy of Sciences (with Yu-Hong Dai, Zhi-Quan Luo)

Max-min fairness linear transceiver design for a multi-user MIMO interference channel

Consider the max-min fairness linear transceiver design problem for a multi-user multi-input multi-output (MIMO) interference channel. When the channel knowledge is perfectly known, this problem can be formulated as the maximization of the minimum signal to interference plus noise ratio (SINR) utility, subject to individual power constraints at each transmitter. We prove in this paper that, if the number of antennas is at least two at each transmitter (receiver) and is at least three at each receiver (transmitter), the max-min fairness linear transceiver design problem is computationally intractable as the number of users becomes large. In fact, even the problem of checking the feasibility of a given set of target SINR levels is strongly NP-hard. We then propose two iterative algorithms to solve the max-min fairness linear transceiver design problem. The transceivers generated by these algorithms monotonically improve the min-rate utility and are guaranteed to converge to a stationary solution. The efficiency and performance of the proposed

algorithms compare favorably with solutions obtained from the channel matched beamforming or the leakage interference minimization.

William Hager, University of Florida (with Hongchao Zhang)

A primal-dual active set algorithm for nonlinear optimization with polyhedral constraints

A primal-dual active set algorithm is developed for nonlinear optimization with polyhedral constraints. The algorithm consists of a non-monotone gradient projection phase implemented by dual active set techniques, an unconstrained optimization phase in the subspace determined by the active set, and a set of rules for branching between the two phases. Global convergence to a stationary point is established. For a nondegenerate stationary point, the algorithm eventually reduces to an unconstrained optimization in a subspace without restarts. Similarly, for a degenerate stationary point where the strong second-order sufficient optimality condition holds, the algorithm eventually reduces to unconstrained optimization in a subspace. A specific implementation of the algorithm is given which exploits a new dual active set algorithm for the gradient projection step and the conjugate gradient algorithm CG_DESCENT for unconstrained optimization.

Yu-Hong Dai, Chinese Academy of Sciences

A perfect example for the BFGS method

Consider the BFGS quasi-Newton method applied to a general non-convex function that has continuous second derivatives. This paper aims to construct a four-dimensional example such that the BFGS method need not converge. The example is perfect in the following sense: (a) All the stepsizes are exactly equal to one; the unit stepsize can also be accepted by various line searches including the Wolfe line search and the Arjimo line search; (b) The objective function is strongly convex along each search direction although it is not in itself. The unit stepsize is the unique minimizer of each line search function. Hence the example also applies to the global line search and the line search that always picks the first local minimizer; (c) The objective function is polynomial and hence is infinitely continuously differentiable. If relaxing the convexity requirement of the line search function; namely, (b), we are able to construct a relatively simple polynomial example.

Optimization in energy systems

Fri.3.MA 549

Stochastic equilibria in energy markets II

Organizer/Chair Daniel Ralph, University of Cambridge · Invited Session

Juan Pablo Luna, Instituto de Matemática Pura e Aplicada – IMPA (with Claudia Sagastizábal, Mikhail Solodov)

Finding equilibrium prices for energy markets with clearing conditions

Energy markets often involve a large number of agents, responsible for production, transportation, storing, or consumption of items such as generated power, distributed energy, stored gas. We analyze an equilibrium model for a market whose agents seek to maximize profits by selling items through a network at a price determined by market clearing. This type of market can be modelled as a large complementarity problem, obtained by gathering the agents profit-maximization conditions together with the market-clearing relation. We consider an alternative model formulated as a generalized Nash equilibrium problem, with agents seeking to minimize costs instead of maximizing profits. Interestingly, this alternative formulation turns out to be equivalent to the more common complementarity model mentioned above. At the same time, it reduces substantially the size of the variational problem and is amenable to decomposition schemes, thus making it possible to consider more realistic situations dealing, for example, with uncertainty and risk for large gas or power networks.

Ozge Ozdemir, ECN (with Gul Gurkan, Yves Smeers)

Generation capacity investments in electricity markets: Perfect competition

We focus on perfectly competitive electricity markets with alternative resource adequacy mechanisms: with VOLL pricing, additional capacity market, and operating-reserve pricing. We model each firm's problem as a two-stage problem where generation capacities are installed in the first stage and generation takes place in future spot market at the second stage. When future spot market conditions are not known in advance (i.e., uncertain demand), we have a stochastic equilibrium model. We assess the extent to which these stochastic equilibrium models can be cast into a two-stage stochastic program. In case of all the market mechanisms except operating-reserve pricing, an equilibrium point can be found by solving a two-stage stochastic program. This provides the prevalence of stochastic programming for solving stochastic equilibrium models. For operating-reserve pricing, while the formulation of an equivalent stochastic optimization problem is possible when

operating reserves are based on observed demand, this simplicity is lost when operating-reserves are based on installed capacities. We illustrate how all these models can be numerically tackled by using the framework of sample path method.

Daniel Ralph, University of Cambridge (with Yves Smeers)

Risk averse long term capacity equilibria: An optimization formulation extending MARKAL

Linear Programming (LP) and other optimization models are standard & useful for long term capacity equilibria, eg, MARKAL for energy capacity equilibria. Such models:

- assume Perfect competition
- can handle uncertainty via risk neutral valuation, ie, expectation with respect to given probability density.

Our main result is that risk aversion can be included in LP/optimization models for long term capacity equilibria:

- assuming Perfect competition
- where valuation of uncertain assets is modelled by Coherent Risk Measures
- by using financial securities which are traded in a Complete Risk Market

Optimization in energy systems

Fri.3.MA 550

MPEC problems and market coupling

Chair Daniel Huppmann, DIW Berlin

Bertrand Cornélusse, n-Side (with Yves Langer, Gilles Meyer, Gilles Scouvar, Mathieu Van Vyve)

Coupling European day-ahead electricity markets with COSMOS

Market coupling allows matching orders submitted by participants of several electricity markets while satisfying network constraints. It maximizes the economic welfare and allows a more efficient usage of market interconnection capacity. Several types of orders are available, including "block orders" that must either be accepted in full or rejected. This problem translates into a MIQP with complicating constraints. Maximizing welfare subject to clearing (matched supply equals matched demand) and network constraints yields acceptance decisions for submitted orders. However some market rules are constraints relating acceptance decisions and market prices, and all integer solutions are consequently not acceptable. We present COSMOS, a dedicated branch-and-cut algorithm to solve this difficult problem. COSMOS runs every day for coupling day-ahead markets of Belgium, France, Germany and the Netherlands. Recent developments integrate specific requirements for the Iberian peninsula, the Italian market and the Nord Pool System. The authors would like to thank the owners of COSMOS, which are currently BelPex, APX-ENDEX and EPEX Spot, for allowing them to communicate on this work.

Johannes Müller, FAU Erlangen-Nürnberg (with Alexander Martin, Sebastian Pokutta)

Linear clearing prices in non-convex european day-ahead electricity markets

The European power grid can be divided into several market areas where the price of electricity is determined in a day-ahead auction. Market participants can provide continuous and combinatorial orders with associated quantities given the prices. The goal of our auction is to maximize the economic surplus of all participants subject to transmission constraints and the existence of linear prices. In general strict linear prices do not exist in the presence of non-convex constraints. Therefore we enforce the existence of linear prices such that no one incurs a loss and only combinatorial orders might see a not realized gain. The resulting model is an MPEC that can not be solved efficiently by standard solvers. We present an exact algorithm and a fast heuristic for this type of problem. Both algorithms decompose the MPEC into a master MIP and price subproblems (LPs). The modeling technique and the algorithms are applicable to all MIP based combinatorial auctions.

Daniel Huppmann, DIW Berlin (with Jan Abrell, Wolf-Peter Schill)

Approximating unit commitment using mathematical programming under equilibrium constraints

Modeling the electricity market and computing optimal dispatch is difficult due to many specific features of the power sector, such as unit commitment (i.e., binary decision variables), non-linear cost functions due to the varying efficiency of a power plant contingent on capacity utilization, and other engineering constraints. Models that capture these aspects grow quickly in complexity and are usually intractable in large-scale applications. Hence, researchers frequently resort to linear models. This, however, raises the question of choosing the parameters for a linear model to describe a highly non-linear interrelation as accurately as possible. We propose a mathematical program under equilibrium constraints (MPEC) to solve this problem; it minimizes the "distance" between a complex unit commitment model (mixed integer non-linear

program, MINLP), and a linear mixed complementarity program (MCP) by setting the parameters of the MCP accordingly. This problem is applied to several data sets and time horizons to derive an understanding of the sensitivity of the obtained parameters. We conclude that our approach offers a feasible path to calibrate linear electricity market models.

PDE-constrained opt. & multi-level/multi-grid meth.

Fri.3.H0111

Preconditioning in PDE constrained optimization

Organizer/Chair Roland Herzog, TU Chemnitz · Invited Session

Markus Kollmann, Johannes Kepler University Linz, Austria (with Walter Zulehner)

Robust iterative solvers for a class of PDE-constrained optimization problems

In this talk we discuss the construction and analysis of robust solution techniques for saddle point problems with a natural block 2-by-2 structure where the left upper and the right lower block are different mass matrices. For these systems, solvers are discussed. Saddle point systems of this structure are, e.g., optimality systems of optimal control problems where the observation domain differs from the control domain or the linearized systems resulting after applying a semi-smooth Newton method to the nonlinear optimality systems of optimal control problems with inequality constraints on the control or the state. As examples we discuss the distributed elliptic optimal control problem and the distributed optimal control problem for the Stokes equations. Numerical examples are given which illustrate the theoretical results.

John Pearson, University of Oxford

Iterative solution techniques for Stokes and Navier-Stokes control problems

The development of efficient iterative methods for the solution of PDE-constrained optimization problems is an area of much recent interest in computational mathematics. In this talk, we discuss preconditioned iterative methods for the Stokes and Navier-Stokes control problems, two of the most important problems of this type in fluid dynamics. We detail the Krylov subspace methods used to solve the matrix systems involved, develop the relevant preconditioners using the theory of saddle point matrices, and present analytical and numerical results to demonstrate the effectiveness of our proposed preconditioners in theory and practice.

Ekkehard Sachs, University of Trier (with Xuancan Ye)

Reduced order models in preconditioning techniques

The main effort of solving a PDE constrained optimization problem is devoted to solving the corresponding large scale linear system, which is usually sparse and ill conditioned. As a result, a suitable Krylov subspace solver is favourable, if a proper preconditioner is embedded. Other than the commonly used block preconditioners, we exploit knowledge of proper orthogonal decomposition (POD) for preconditioning and achieve some interesting features. Numerical results on nonlinear test problems are presented.

PDE-constrained opt. & multi-level/multi-grid meth.

Fri.3.MA 415

PDE constrained optimization with uncertain data

Organizer/Chair Volker Schulz, University of Trier · Invited Session

Hanne Tiesler, Jacobs University & Fraunhofer MEVIS (with Robert Kirby, Tobias Preusser, Dongbin Xiu)

The use of stochastic collocation schemes for the solution of optimal control problems, constrained by stochastic partial differential equations (SPDE), is presented. The constraining SPDE depends on random data and accordingly, the randomness will propagate to the states of the system, whereas the control is assumed to be deterministic. There exist different efficient numerical schemes for the solution of SPDEs, one of them is the stochastic collocation method, which is based on the generalized polynomial chaos. For the minimization of the constrained optimization problems we combine the stochastic collocation method with a gradient descent method as well as a sequential quadratic program (SQP). In the presented work, different optimization problems are considered, i.e., we define different objective functions of tracking type to show different application possibilities. The functions involve several higher order moments of the random states as well as classical regularization of the control. The developed methods are compared to the widely used Monte Carlo method. Numerical results illus-

trate the performance of the new optimization approach with stochastic collocation.

Claudia Schillings, University Trier (with Volker Schulz)

On the influence of robustness measures on shape optimization with stochastic uncertainties

The unavoidable presence of uncertainties poses several difficulties to the numerical treatment of optimization tasks. In this talk, we discuss a general framework attacking the additional computational complexity of the treatment of uncertainties within optimization problems. Appropriate measure of robustness and a proper treatment of constraints to reformulate the underlying deterministic problem are investigated. In order to solve the resulting robust optimization problems, we propose efficient discretization techniques of the probability space as well as algorithmic approaches based on multiple-setpoint ideas in combination with one-shot methods. Finally, numerical results considering optimal aerodynamic design under shape uncertainties will be presented.

Matthias Heinkenschloss, Rice University

A trust-region based adaptive stochastic collocation method for PDE constrained optimization with uncertain coefficients

Many optimization problems in engineering and science are governed by partial differential equations (PDEs) with uncertain parameters. Although such problems can be formulated as optimization problems in Banach spaces and derivative based optimization methods can in principle be applied, the numerical solution of these problems is more challenging than the solution of deterministic PDE constrained optimization problems. The difficulty is that the PDE solution is a random field and the numerical solution of the PDE requires a discretization of the PDE in space/time as well as in the random variables. As a consequence, these optimization problems are substantially larger than the already large deterministic PDE constrained optimization problems.

In this talk we discuss the numerical solution of such optimization problems using stochastic collocation methods. We explore the structure of this method in gradient and Hessian computations. We use a trust-region framework to adapt the collocation points based on the progress of the algorithms and structure of the problem. Convergence results are presented. Numerical results demonstrate significant savings of our adaptive approach.

Stochastic optimization

Fri.3.MA 141

Scenario generation in stochastic programming

Organizer/Chair Mihai Anitescu, Argonne National Laboratory · Invited Session

Sanjay Mehrotra, Northwestern University (with Michael Chen, David Papp)

New results in scenario generation for stochastic optimization problems via the sparse grid method

We study the use of sparse grid methods for the scenario generation (or discretization) problem in stochastic optimization problems when the uncertainty is modeled using a continuous multivariate distribution. We show that, under a regularity assumption on the random function, the sequence of optimal solutions of the sparse grid approximations converges to the true optimal solution as the number of scenarios increases. The rate of convergence is also established. An improvement is presented for stochastic programs in the case when the uncertainty is described using a linear transformation of a product of univariate distributions, such as joint normal distributions. We numerically compare the performance of sparse grid methods with quasi-Monte Carlo and Monte Carlo scenario generation. The results show that the sparse grid method is very efficient if the integrand is sufficiently smooth, and that the method is potentially scalable to thousands of random variables.

John Birge, University of Chicago

Cut generation for serially dependent multistage stochastic optimization models

Several variations of Monte Carlo methods for multistage stochastic programs rely on serial independence to obtain valid cuts (supporting hyperplanes) on a lower-bounding value function approximation. Many practical problems, however, have some form of serial dependence. In particular, many financial models involve auto-regressive processes with significant auto-correlations. This talk will describe how to obtain valid cuts in this framework so that extensions of methods such as stochastic dual dynamic programming (SDDP), abridged nested decomposition (AND), and others can be extended to a more general environment.

Tito Homem-De-Mello, Universidad Adolfo Ibañez (with Vitor de Matos, Erlon Finardi)

On scenario generation methods for a hydroelectric power system

We study a multi-stage stochastic programming model for hydrothermal energy planning in Brazil, where uncertainty is due to water inflows. We discuss some methods for generation of scenario trees

that can be used by an optimization algorithm to solve the problem. Although the original input process is modeled with an periodic autoregressive model, by making a transformation we can reduce the input process to one that is stage-wise independent. That in turn allows us to proceed with generating scenarios stage-by-stage following the approach in Mirkov and Pflug (2007). The algorithm we propose hinges on the stage-wise independence property and consists of two phases: first, we generate a scenario tree where the distribution in each stage is approximated by a discrete distribution with large number of points; then, we apply a reduction method to find a distribution with smaller support that minimizes the Wasserstein distance to that discrete distribution. We show how this minimization problem can be solved with a structured binary linear program. Some numerical results are presented to illustrate the ideas.

Stochastic optimization

Fri.3.MA 144

PDE constrained stochastic optimization

Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen · Invited Session

Rüdiger Schultz, University of Duisburg-Essen (with Sergio Conti, Harald Held, Martin Pach, Martin Rumpf)

Shape optimization under uncertainty via stochastic optimization

Shape optimization with linearized elasticity and stochastic loading is put into the framework of two-stage stochastic programming. Principal model set ups, both risk neutral and risk averse, are discussed. Outlines of solution procedures and some computational experiments complete the talk.

Benedict Geihe, Bonn University

A two-scale approach for risk averse shape optimization

We investigate macroscopic geometries with underlying periodic lattices of fine scale structures. These details are supposed to be parametrized via a finite number of parameters over which we optimize. Risk averse stochastic cost functionals are taken into account. We employ a two-scale approach based on boundary elements for the elastic problem on the microscale and finite elements on the macroscale.

Tony Huschto, University of Heidelberg (with Sebastian Sager)

Solving stochastic optimal control problems by a polynomial chaos approach

In optimal control problems driven by stochastic differential equations, the detection of optimal (Markovian) decision rules is a very challenging task. Explicit solutions can be found in only very few cases by considering the corresponding Hamilton-Jacobi-Bellman equation. Thus numerical methods, e.g., based on Markov chains, have attracted great interest.

In this contribution, we introduce a new methodology for solving continuous finite-horizon stochastic optimal control problems. We utilize ideas for approximating stochastic differential equations within the framework of Polynomial Chaos and expand this to reformulate stochastic optimal control problems directly into deterministic ones. This allows us to use Bock's direct multiple shooting method, a state of the art simultaneous method to solve optimization and simulation tasks at the same time. We implement different approaches to preserve the feedback character of the optimal decision rules. Numerical examples illustrate this new methodology and show the validity of the developed reformulations.

Telecommunications & networks

Fri.3.H 3503

Robust network design and applications

Organizer/Chair Christian Raack, Zuse Institute Berlin · Invited Session

Agostinho Agra, University of Aveiro (with Marielle Christiansen, Rosa Figueiredo, Lars Hvattum, Michael Poss, Cristina Requejo)

The robust vehicle routing problem with time windows

This work addresses the robust vehicle routing problem with time windows. We are motivated by a problem that arises in maritime transportation where delays are frequent and should be taken into account. Our model only allows routes that are feasible for all values of the travel times in a predetermined uncertainty polytope, which yields a robust optimization problem. We propose two new formulations for the robust problem, each based on a different robust approach. The first formulation extends the well-known resource inequalities formulation by employing robust programming with recourse. We propose two techniques, which, using the structure of the problem, allow to reduce significantly the number of extreme points of the uncertainty polytope. The second formulation generalizes a path inequalities formulation to the uncertain context. The uncertainty appears implicitly in this formulation, so that

we develop a new cutting plane technique for robust combinatorial optimization problems with complicated constraints. In particular, efficient separation procedures are discussed. We compare the two formulations on maritime transportation instances.

Sara Mattia, IASI-CNR

The robust network loading problem

The Robust Network Loading (RNL) problem is a generalization of the well known Network Loading (NL) problem. Given a graph with capacity installation costs for the edges, the RNL problem consists of choosing minimum cost integer capacities to serve all the demands belonging to a given polyhedron of feasible traffic matrices. If the routing scheme must be the same for all the matrices, it is called static or oblivious; if it can be changed according to the matrix, it is called dynamic. If each point-to-point demand in the matrix must be routed using a single path, the flows are called unsplittable, otherwise they are said to be splittable. In this talk we present an algorithm for solving the RNL with dynamic routing and splittable flows and a preliminary comparison between the static and the dynamic approach.

Fabio D'Andreagiovanni, Zuse Institute Berlin (ZIB) (with Christina Büsing)

On the adoption of multi-band uncertainty in robust network design

Handling uncertainty in the design of telecommunication networks has become a key challenge for leading network operators. Uncertainty in Network Design has been mainly tackled by the Bertsimas-Sim model (BS). However, the central assumption of BS that the deviation band of each uncertain parameter is single may be too limiting in practice: experience indeed suggests that relevant deviations also occur internally and asymmetrically over the band. Breaking the band into multiple sub-bands looks thus advisable.

In this work, we study the robust counterpart of an LP with uncertain coefficient matrix, when a multi-band uncertainty set is considered. We show that the robust counterpart corresponds to a compact LP formulation and that separating robustness cuts corresponds to solving a min-cost flow problem. Finally, we assess the effectiveness of our approach on realistic instances of robust network design problems considered by our industrial partners.

- [1] D. Bertsimas, M. Sim, The Price of Robustness, *Oper. Res.* 52 (1), 35–53, 2004
- [2] C. Büsing, F. D'Andreagiovanni, New results about multi-band uncertainty in Robust Optimization, to appear in *Proc. of SEA2012*

Variational analysis

Fri.3.H 2051

Monotone operators

Organizer/Chair Radu Ioan Bot, Chemnitz University of Technology · Invited Session

Radu Ioan Bot, Chemnitz University of Technology (with Sorin-Mihai Grad)

Approaching the maximal monotonicity of bifunctions via representative functions

In this talk we provide an approach to maximal monotone bifunctions by means of the theory of representative functions. Thus we extend to nonreflexive Banach spaces recent results due to A. N. Iusem (*Journal of Convex Analysis*, 2011) and, respectively, N. Hadjisavvas and H. Khatibzadeh (*Optimization*, 2010), where sufficient conditions guaranteeing the maximal monotonicity of bifunctions were introduced.

Marco Rocco, Bank of Italy (with Juan Enrique Martínez-Legaz)

On a surjectivity-type property of maximal monotone operators

In this paper we carry on the inquiry into surjectivity and related properties of maximal monotone operators initiated in Martínez-Legaz, Some generalizations of Rockafellar's surjectivity theorem (*Pac. J. Optim.*, 2008) and Rocco and Martínez-Legaz, On surjectivity results for maximal monotone operators of type (D) (*J. Convex Anal.*, 2011). Providing a correction to a previous result, we obtain a new generalization of the surjectivity theorem for maximal monotone operators.

Szilárd László, Babes-Bolyai University, Cluj-Napoca

Regularity conditions for the maximal monotonicity of the generalized parallel sum

We give several regularity conditions, both closedness and interior point type, that ensure the maximal monotonicity of the generalized parallel sum of two strongly representable maximal monotone operators, and we extend some recent results concerning on the same problem. Our results are based on the concepts of representative function and Fenchel conjugate, while the technique used to establish closedness type, respectively interior-point type regularity conditions, that ensure the maximal monotonicity of this generalized parallel sum, is stable strong duality. We give an useful application of the stable strong duality for the problem involving the function $f \circ A + g$, where f and g are proper, convex and lower semicontinuous functions, and A is a linear and continuous operator. We also introduce some new generalized infimal convolution formulas, and establish some results concerning on their Fenchel conjugate.

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