OPTIMA

№ 24

MATHEMATICAL PROGRAMMING SOCIETY NEWSLETTER JUNE 1988

Journal Series B Replaces Studies

IN 1988, all members of the Mathematical Programming Society will begin to receive ***Mathematical Programming, Series B (MPB)***, in addition to the journal ***Mathematical Programming***, which will now be referred to as ***Series A***. ***MPB*** replaces the ***Mathematical Programming Studies***, which ceases publication.

In many respects, ***MPB*** will serve a function similar to that performed by the ***Studies***. Generally, each issue will deal with a unified subject of interest to Society members. Each year we will publish three issues dealing with theoretical, computational and applied aspects of mathematical programming. An issue may be a collection of articles or a single research monograph. For example, three of our first issues will be proceedings of recent conferences: The Martin Beale Memorial Symposium (edited by M.D. Powell), the Symposium on Parallel Computing in Mathematical Programming (edited by O. Mangasarian and R. Meyer) and the Capri Workshop on Applications of Combinatorial Optimization (edited by M. Padberg, G. Rinaldi and A. Sassano).

Because of the diversity of interests of the Society membership, it is neither likely nor intended that all issues will have the same interest for all members. It is our goal to maintain a broad balance of topics and our hope that all members will find something of interest in each three issue volume.

A major difference between ***MPB*** and the ***Studies*** is that ***MPB*** has an editorial board separate from ***Series A***. The responsibilities of its members are to ensure that a high editorial standard is maintained, to assist in the generation of new issues and to provide advice concerning the acceptance of proposals for issues received. Most issues will be edited by a guest editor who will be responsible for carrying out the editorial process in accordance with our standards.

A main objective is to continue to publish high quality collections of papers dealing with the various aspects of linear, nonlinear and integer programming and continuous and discrete optimization. In addition, ***MPB*** provides us with an opportunity to be proactive rather than reactive. We hope to be able to produce timely issues on topics of current interest. One such topic is the application of mathematical programming to real world problems as well as other branches of science. Several issues will focus on this over the next few years. Another area of

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Conference Note

Workshop on Mathematical Programming

Catholic University of Rio De Janeiro, BRAZIL
October 10-14, 1988

Main Themes:
Combinatorial Optimization, Nondifferentiable Optimization, Projective Algorithms, Applications

Program Committee:
Celso Ribeiro, Chairman, Michel Balinski, Martin, Nelson Maculan, Philippe Mahey, William Pulleyblank

Invited Lecturers:
J. Araoz, M. Balinski, F. Barahona, R. A. Cuninghame-Green, J. Ferland, C. Gonzaga, M. Grotschel, P. Hammer, P. Hansen, J. B. Hiriart-Urruty, K. C. Kiwiel, B. Korte, F. Louveaux, F. Maffioli, N. Maculan, P. Mahey, M. Minoux, V. H. Nguyen, M. Padberg, W. Pulleyblank, C. Ribeiro, R. T. Rockafellar, J. Spingarn, M. Todd, P. Toth, A. Weintraub

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INTERNATIONAL MPS SYMPOSIUM CONVENES IN TOKYO AUGUST 29-SEPTEMBER 2

Call for Papers

A SPECIAL ISSUE OF MATHEMATICAL PROGRAMMING Series B devoted to large scale problems is being prepared under the joint editorship of A.R. Conn, N.I.M. Gould and Ph.L. Toint. The emphasis is intended to be large scale nonlinear programming rather than linear programming. However, articles that emphasize applications, algorithms and/or theory that is not primarily linear programming oriented could be suitable and are solicited.

Mathematical Programming Series B is now on a similar schedule to Series A with similar standards for publication and the same circulation. The advantage of a special issue, besides collecting articles on a coherent theme, is that the refereeing process can often be expedited.

If you have a suitable paper for such an issue you are invited to submit it to one of the editors.

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The deadline for submission is August 1, 1988 for the issue that is to be published in 1989. Late submissions, an excess of submissions, etc., would automatically be considered for Mathematical Programming Series A, unless the author wishes otherwise.

- A. Conn

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Operations Research Group
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BOOK REVIEWS

Optimal Block Search

By L. Weixian
Heldermann, Berlin, 1984
ISBN 3-88538-205-9

Let f be a unimodal function in [a,b]. Kiefer, in 1953, showed that the golden section method has certain optimal properties with respect to a sequential search for a maximum. Since then there have been many articles dealing with extensions of this result, e.g., Avriel, Beamer and Wilde in 1966, 1969 and 1970.

In the beginning of the seventies when the so-called "cultural revolution" came towards an end, there were many Chinese mathematicians who were enthusiastic about such extensions. The book reviewed is designed to summarize the results obtained in that period. It consists of seven chapters: (1.) Introduction, (2.) Strategies of finite order, (3 and 4.) The optimal block search problem, (5.) Strategies of infinite order, (6 and 7.) Sequential search with time delay. The author made an attempt to give a unifying approach to these results, but I have to say his efforts cannot be counted as successful. When the author introduced the terms "approximation" and "remaining interval," he referred to a fixed function (p.4). From this he introduced a concept "state" (p.5,1.-7). But this does not agree with formal definition of "state" (Def. 1.4). Meanwhile, the formal definitions of approximation and remaining interval are given only in terms of state. On p.4, it says "since we have seen that the optimal point of a unimodal function is within the remaining interval," the author referred again to a function. It seems that the author intended to avoid use of a specific function in defining his "K-strategy" but could not avoid it. In fact, the first chapter is full of conceptual confusions. Nevertheless, the remaining part is readable. - Yue Minyi

Graph Theory
Encyclopedia of Mathematics, Volume I

By W. T. Tutte
Addison-Wesley, 1984
ISBN 0-201-13520-5

W.T. Tutte is without doubt one of the pioneers of graph theory in the sense that he has been personally responsible for inventing many of the subdisciplines of that area which occupy graph theorists today. But it would be grossly unfair to interpret the term "pioneer" only in the sense of pollination! From early on, he has striven to put graph theory on a firm footing with respect to rigor. The present book is a beautiful culmination of these efforts to "do things right" in graph theory.

But Tutte is an indivdualist too, to say the least, in his approach to graph theory and this side of the man is strongly reflected in this book, both with respect to the selection of topics and his treatment of them. A number of other important topics in graph theory are not covered in this book. This is not really a complaint but perhaps just an indication that any attempt to write an "Encyclopedia" on any mathematical discipline is frought with danger!

In Chapter I, the author gets us off the ground by defining graphs and subgraphs and providing a bevy of beginning definitions for the reader. We would be remiss, however, if we did not point out at once that Tutte's definitions and notation do not always agree with those of a large part of the rest of the graph theory community. (For example, his "binding number" is quite a different thing from the parameter of the same name first introduced and studied by Woodall.) But the tone is set for rigor here at the onset, as Tutte presents a particularly careful treatment of vertices of attachment and the bridges of a graph.

In Chapter II, the author introduces the idea of edge contraction, wisely indicating to the reader early in the game that proofs by induction on the number of edges of a graph (edge deletion) and on the number of points of a graph (edge contraction) abound in graph theory. Here we also are first introduced to the concept of a graph *minor*. The idea of a minor is of central importance to Tutte, not only in the context of graphs, but in the field of matroid theory, yet another fruitful branch of combinatorics which must list Tutte as one of the principal founders.

The *vertex* connectivity version of Menger's famous minimax theorem is then introduced and proved. Tutte notes that Menger's result has an important analogue in transportation theory. However, this analogue, the max-flow min-cut theorem, is not seen until Chapter VI where it is stated and proved and the directed vertex version of Menger's theorem is derived as a corollary. Unfortunately, the other two main versions of Menger's theorem, namely, the directed and undirected *edge* variants, are not mentioned at all.

But let us backtrack slightly. The reader encounters on page 36 the first mention of the concept of *duality* in graph theory. This portent of things to come is to be applauded as duality ultimately becomes a centerpiece of the book as a whole. (But more about this below.)

Next the author uses Menger's theorem to prove the classical result of P. Hall on bipartite matching. It might have been nice here to mention the minimax result of D. König which is equivalent to Hall's result and which actually was proved by König after finding an error of omission in the first proof offered by Menger of his own result.

In the notes at the end of this chapter, Tutte mentions a conjecture attributed to Kruskal on minors in cubic graphs. This result has recently been proved by Robertson (once a student of Tutte) and Seymour as a consequence of their work on graph minors and their proof of the celebrated conjecture of Wagner.

In Chapter III we are presented with Tutte's rigorous development of the theory of 2-connection in graphs. Among other things, he shows that all 2-connected graphs can be obtained from smaller ones by adding paths joining distinct vertices. The *block graph* (perhaps more widely known as the *block-cutpoint tree*) is then developed. Finally, the

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author reminds us again of the duality yet to come by proving in the last theorem of the chapter that for every edge in a 2-connected graph, either the graph with the edge deleted or the graph with the edge contracted retains the property of being 2-connected.

Chapter IV deals with 3-connection and culminates in Tutte's beautiful Wheel Theorem for producing all 3-connected graphs. He begins with his own definition of 3-connection which, he is quick to point out, is slightly different from the more common definition of this property. Indeed, for graphs without loops or multiple edges, the two definitions coincide. Tutte's theory of 3-connection presented in this chapter formed the core of one of his earlier books devoted entirely to the study of connectivity in graphs.

This brings the reader to Chapter V which deals with the topic of graph reconstruction. The brevity of this chapter-the shortest in the book-belies the impact of Tutte's own work on this topic. Here he is content with a short survey of results mostly of a counting nature.

Digraphs are introduced and studied in Chapter VI. The B(de Bruijn)E(van Aardenne-Ehrenfest)S(Smith)T(Tutte) Theorem relating the number of closed Eulerian trails and the number of spanning arborescences is proved as is the classical result of Euler relating the existence of a closed Eulerian trail and equality of in- and outdegrees of a connected digraph. Then stressing analogies with electrical network theory, the author defines the so-called *Kirchhoff matrix* and relates determinants of certain submatrices of this matrix to the number of spanning arborescences emanating from a root point in the well-known *Matrix-Tree Theorem*. Kirchhoff's Laws for digraphs are treated next and the chapter closes with a treatment of the max-flow min-cut theorem.

Chapter VII begins with a development of a very general theory of alternating paths which is then brought to bear in proving Tutte's own *f*-factor theorem. Let *f* be a function which assigns to each point of a graph a non-negative integral value bounded above by the degree of the point. An *f-factor* is a spanning subgraph which has as its degree the value of *f* at each point. The *f*-factor theorem states that given such a function *f* on the vertices of a graph, then either the graph has an *f*-factor or a certain type of "blocking configuration" called an *f*-barrier.

Almost hidden from view here is one of Tutte's most famous theorems, the *1-factor theorem*, which gives necessary and sufficient conditions for an arbitrary (i.e., not necessarily bipartite) graph to have a perfect matching. This result is arguably the single most important result in all of matching theory.

The chapter ends with a nice application of *f*-factor theory to obtain a clasical result due to Erdös and Gallai which characterizes which sequences of non-negative integers are the degree sequences of graphs.

Chapter VIII is, in the opinion of this reviewer, the high point of the entire book. The author undertakes the construction of an algebraic theory of duality for graphs. He begins by developing the theory of chain-groups in the abstract. He then applies chain groups to graphs incorporating the "duality" of circuits and bonds in the more general setting of dual chain groups. To the reviewer's knowledge, this approach cannot be found anywhere other than in the work of Tutte. In the final section of the chapter, Tutte gleans from the properties of chain groups two which together form one (of a number) of the axiom systems for a *matroid*. He then observes that the concept of matroid is broad enough to encompass both chain groups and graphs.

Graph polynomials form the subject matter of Chapter IX. Starting with the very general idea of a *V-function*, Tutte specializes first to the concept of a *dichromatic polynomial* and finally to the *chromatic polynomial* $P(G;\lambda)$. If the indeterminant λ is set equal to a positive integer n, then $P(G;n)$ is the number of vertex colorations of graph G in n colors. The *Four Color Theorem* can be expressed as the assertion that $P(G;4) \geq 1$ for all planar graphs G.

The author also includes in this chapter a proof of Brooks' Theorem which states that if a graph G has maximum degree $\Delta \geq 3$ and is not complete, then G has a vertex coloration in no more than Δ colors. Also the author presents a theorem dual to that of Grinberg which deals with the existence of Hamilton circuits for planar graphs, but Tutte's version holds even when the planarity demand is dropped.

Next, Tutte turns to the concept of a *flow polynomial* which, at least for connected graphs, is dual (in the setting of chain-groups) to that of chromatic polynomial. He uses the language of flow polynomials to state the still unsolved *Five Flow Conjecture*. He then turns to a brief outline of the theory of Tait colorings and introduces us to that sinister animal, the "snark"!

Once again, duality is the motivating influence as Tutte next introduces a polynomial in two variables called the *dichromate*. It is symmetrically related, in a sense, to the two dual functions, the chromatic polynomial and the flow polynomial. In addition, the dichromate is quite intimately related to the set of spanning trees in the case when the graph under consideration is connected. Call a graph property *reconstructible* if it can be inferred to hold for a graph G if it holds for all the vertex-deleted subgraphs of G. (This term is actually introduced earlier in Chapter V on reconstruction.) Tutte proves his dichromate is reconstructible and from this fact it follows that a number of other graph properties are reconstructible as well. Among these are the dichromatic polynomial, the chromatic polynomial, the flow polynomial, the chromatic number, whether or not the graph as a 5-flow, the number of Hamilton circuits and, at least for graphs without loops or multiple lines, the characteristic polynomial.

Chapter X on combinatorial maps is a gem. Here Tutte carefully introduces and develops a *purely combinatorial* theory of maps, surfaces, orientability and non-orientability, Euler Characteristic, planarity and genus. Heretofore, purely topological concepts all! The author even obtains a combinatorial version of the classification theorem for both orientable and non-orientable surfaces.

In Chapter XI, he concentrates on planar graphs. There is even a combinatorial analogue to the Jordan Curve Theorem, another famous result which, at least up to now, has been firmly planted in the topologists' garden! Tutte procedes to get an algorithm for planarity testing as well as proofs of the classical characterizations of planar graphs due to MacLane and to Kuratowski. Sadly, the chapter and book are then brought to a close without a mention of another of Tutte's most celebrated theorems, namely, that a 4-connected planar graph must always have a Hamilton circuit. (However Nash-Williams does mention the result in his foreward to the book.)

This book is unique both in its approach to graph theory and in the rigor the author brings to the discipline. There seems to be no doubt that duality is always in the back of the author's mind throughout, as the book pivots on this notion.

By the very uniqueness of this approach, however, the book would profit well by the inclusion of more examples. But to the reviewer, the only truly annoying facet of this book is the failure to include an *index of terms and symbols*. The text is remarkably free of misprints. The reviewer found only a few, the most amusing being the running head on page 241 which tells the reader that he is studying Trait colorings!

In closing, the reviewer feels bound to emphatically disagree with the remarks on the dust cover which begin with the phrase "Designed for the non-specialist,....."! This book is for the *experienced* graph theorist, if ever a book were. Having said that, however, I firmly believe that this truly important book should be in the library of every practicing graph theorist. - M. D. Plummer

Map Coloring, Polyhedra, and the Four Color Problem

By D. Barnette
John Wiley, Chichester, 1984

Rarely before has a famous and long-standing problem aroused such strong emotions as the four-color problem. On the negative side it was claimed that the problem was of no mathematical significance and the eventual solution preposterous. On the other hand, the opinion was also heard that this problem had almost single-handedly given birth to a whole new and ever more important branch of mathematics - graph theory, and that even the solution with its manyfold implications on the future of mathematical research may prove to be of lasting significance. The author of the book under review squarely throws his weight on the positive side, and he does so in a light-handed and thoroughly enjoyable way. Professor Barnette is a geometer and he more or less confines his subject to the connections between maps, graphs and polyhedra. The result is a delight for both the insider and the casual reader who just wants to learn what this coloring business is all about. Along the way he gets acquainted with Euler's equation, Hamiltonian circuits, isomorphism and duality of maps, Steinitz' and Eberhard's theorems to name just a few of the topics. Numerous exercises, illustrations and historical remarks keep up an easy flow of reading. Barnette shows how all these concepts emerged in the search for a proof of the four-color conjecture, how they were refined, altered, strengthened, and - failed. "What good is it?" is the title of the last section. After reading Barnette's magnificent little book one should not want for an answer. - M. Aigner

Discrete and Combinatorial Mathematics

By R. P. Grimaldi
Addison Wesley, Amsterdam, 1985
ISBN 0-201-12590-0

With his book R. P. Grimaldi gives "an applied introduction" (subtitle) to the basic areas of discrete and combinatorial mathematics. According to the objective to address to the beginning student with only a background in high school algebra, the first half of the book is concerned with introductory chapters such as the fundamental principles of counting, enumeration in set theory, functions and relations, the set theory of strings, the system of integers, the principle of inclusion and exclusion, rings and modular algebra, and boolean algebra. The next part of the book deals with combinatorial topics as generating functions, recurrence relations, groups, coding theory and Polya's method of enumeration, andfinite fields and combinatorial design. In the last sections of the book, Grimaldi presents a short introduction to graph theory with special attention to trees (for their application to data structures) and first steps in combinatorial optimization, as weighted trees, the max-flow-min-cut theorem and bipartite matching.

All topics presented in this book are illustrated by some simple examples (applications), and each subsection is followed by a series of exercises - most of them with solutions. Thus the student may get familiar with combinatorial subjects. The section "summary and historical review" following each chapter contains references for further reading.

Grimaldi gave his book the structure of a lecture (with many examples), so it might serve well as a companion through a course on discrete and combinatorial mathematics for undergraduate students. - Jörg Rieder

Multiple Criteria Optimization: Theory, Computation, and Application

By Ralph E. Steuer
John Wiley and Sons, Chichester, 1986

This textbook presented by Steuer will hold very soon the cardinal place of a highly esteemed standard work on the area of decision making with multiple objectives, especially in the field of linear and nonlinear programming with multiple criteria. It contains a great

continues

BOOK REVIEWS

number of numerical examples and figures which serve to convey easily the complicated matter of multiple criteria decison making and algorithms. Also many references are given, ordered by chapters and recommended as reading for further detailed studies. The book is written at a high level but makes nevertheless the theoretical expositions easy to understand. The impressive combination of the didactically skillful processing of the presented matter with the broad bibliographical foundation of the analytical deliberations will certainly guarantee the success of this textbook at universities. Steuer has succeeded in a convincing manner with this book for beginners as well as for experts in the area of decision making with multiple criteria.

The book contains 17 chapters. Chapter 1 is a short introduction. The mathematical background needed for the following expositions is prepared in Chapter 2. The basic findings and theorems of set thoery, linear algebra and properties of extreme points polyhedra and matrices are given. Chapter 3 presents the theory of linear programming with one objective. The determination of all alternative optima in Chapter 4 is directly linked to this.

Then in chapers 5-9 the theory of linear programming with multiple criteria is developed. In this context Steuer deals with the importance of the notions of efficiency, dominance and Pareto-optimality for these cases. Relations to parametric programming are pointed out. Within these presentations the stress is on estimating optimal weighting vectors for given goal vectors in order to determine an optimal compromise solution for multiple criteria decision problems. Subsequently, the author demonstrates the possibilities of applying algorithms available today for solving vector maximum problems.

Chapter 10 is devoted to the concept of goal programming. In chapter 11 the interesting question is to what extent a representative subset will be sufficient to solve a problem formulated on a larger set of decision alternatives. Chapter 12 deals briefly with problems of multiple objective linear fractional programming.

Additional focal points of the book are chapters 13-15, where interactive solution approaches for multiple objective decision problems are discussed. Chapter 16 gives applications, which show in an attractive way how the methods presented can be implemented in order to solve practical decison problems with multiple objectives. The concluding chapter 17 addresses future developments.

Summing up one can say that the textbook of Steuer recommends itself for an intensive reading. The reviewer has read it with joy and profit. - Günter Fandel

Applied Mathematical Programming for Engineering and Production Management

By Turgut Ozan
Prentice Hall, 1986
ISBN 0-8359-0026-6

From the Preface: "This book has been written as a first course in mathematical programming for engineering and production management students and for practicing engineers and managers.... The basic features emphasized in writing the book were simplicity of explanations, avoidance of rigorous theory (without being superficial), and concentration on model building with single and multiple objectives."

Chapter 1 presents the fundamental concepts, while the simplex method is given in Chapter 2. Dual simplex method and sensitivity analysis follow in Chapter 3 and applications (model building, case studies) in Chapter 4. The transportation problem and its extensions are presented in Chapters 5 and 6 and integer programming in Chapters 7 and 8. The last four chapters deal with multiple objective programming, project management techniques and dynamic programming.

Let us compare in more detail the present book with the text *Applied Mathematical Programming* by S. P. Bradley, A. C. Hax & T. L. Magnanti (Addison-Wesley, Reading, MA, 1977) which is used at many universitites for the first course in mathematical programming. Bradley, Hax and Magnanti cover slightly more material (revised simplex method, large scale systems, nonlinear programming) though PERT-type activities are covered in less detail. The reviewer feels, moreover, another advantage of Bradley, Hax and Magnanti is that the length of the initial chapters is more balanced: Chapter 1 (introduction of basic concept and graphical solution of 2-dimensional LP problems) is shorter, duality and sensitivity analysis are treated in separate chapters, as are general remarks on MP applications and case studies.

On the other hand, this book also has many advantages. Some examples (from mechanical and electric engineering) were quite new and unusual (at least for the reviewer) and it bibliography contains many references from the last decade as well. It gives references to commercially available computer programs too and quotes excerpts from various surveys (like the ones on the organizational location of the OR/MS groups within a firm, or on the distribution of the major field of study of the directors and staff of the OR/MS departments in large U.S. industrial corporations).

Summarizing, the book can be recommended as a text for a first course in mathematical programming. - András Recski

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special interest is high quality computational work. I hope to be able to produce issues which deal with the problems encountered when implementing mathematical programming algorithms as well as their solutions. Also, I hope to be able to produce issues focusing on the strong emerging links with computer science.

I strongly encourage members of the Society who have an idea for a suitable issue to discuss it with me or another member of the board. If it appears promising, a proposal will be requested which will be circulated to appropriate members of the board, after which a decision will be made.

I am personally very pleased by the opportunity *MPB* provides and am looking forward to its development as a high quality publication of the Society.

–W.R. Pulleyblank

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An International Workshop on Generalized Concavity, Fractional Programming and Economic Applications was held in Pisa, Italy, May 30-June 1. For information contact Prof. Alberto Cambini, Dipartimento di Statictica e Matematica Applicata all'Ecomomia, Via Ridolfi 10, 56100 Pisa. . . OPTIMA 22 incorrectly reported that the Gold Medal of EURO had been awarded to Peter Hammer rather than Pierre Hansen, the actual recipient. Peter Hammer received the Docteur es Sciences Honoris Causa from the Swiss Federal Institute of Technology. . . A Workshop on Supercomputers and Large-Scale Optimization was held May 16-18 at the University of Minnesota. For further information contact J.B. Rosen, Computer Science Department, 136 Lind Hall, Minneapolis, MN 55455. . . COAL member Stein W. Wallace, formerly of Chr. Michelsen Institute, Bergen, Norway has joined Haugesund Maritime College, Skaregaten 103, N-5500 Haugesund, Norway. . . F.H. Clarke, V.F. Dem'yanov and F. Giannessi are directing a workshop on Nonsmooth Optimization in Sicily, Italy, June 19-July 1, 1988.

Deadline for the next OPTIMA is October 1, 1988.

Books for review should be sent to the Book Review Editor, Prof. Dr. Achim Bachem, Mathematiches Institute der Universität zu Köln, Weyertal 86-90, D-5000 Köln, West Germany.

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