OPTIMA

MATHEMATICAL PROGRAMMING SOCIETY NEWSLETTER

Number 17
December 1985

Society Prizes Awarded At Boston Meeting

Dick Cottle Resigns, Mike Todd New Editor-In-Chief

Publication Matters at the Boston Symposium

After a term of six years as a distinguished Editor-in-Chief of *Mathematical Programming* and the *Mathematical Programming Studies,* Richard W. Cottle has decided to resign. The Council of the Society has expressed its sincere gratitude to Dick for his outstanding contributions to the Society in this central function.

It is a pleasure to announce the appointment of Michael J. Todd as our new Editor-in-Chief. Mike will assume editorial responsibility for the Journal and the Studies on January 1, 1986, for a term of three years, which is renewable. In cooperation with the Publications Committee of the Society, Mike will make recommendations on various crucial issues related to the Journal and the Studies.

One of these issues is the publication frequency of the Journal. From the beginning in 1971, we published two volumes (six issues) per year. In 1982 this was increased to three volumes per year as a remedy for unacceptable backlogs. It helped; the backlog is now at an all-time minimum of six months. While this is attractive for our authors, it can be unnerving from an editorial point of view. A return to the original publication frequency might eventually be unavoidable. Please view this as an invitation to submit!

Another issue is the status of the Studies and their relationship to the Journal. A Study is "devoted to a unified

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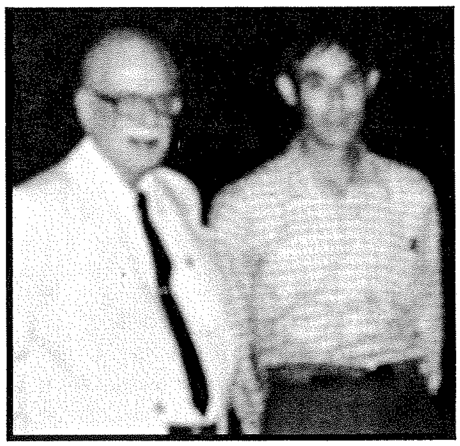

William Orchard-Hays with Michael Saunders

First Orchard-Hays Prize to Michael Saunders

The first Orchard-Hays Prize was awarded at the Boston meeting to **Michael Saunders** for his work in computational mathematical programming. Saunders is at the Stanford Optimization Laboratory, Department of Operations Research, Stanford University. The award is administered by the Society's Committee on Algorithms.

The award citation reads: "On this fifth day of August 1985, for his innovative mathematical work which has advanced significantly the design and implementation of nonlinear programming algorithms, and for establishing the standard in versatile, reliable and available software in this field, initially through early versions of MINOS done jointly with B. Murtagh, and more recently through a variety of projects with P. Gill, W. Murray and M. Wright."

-Karla Hoffman

Ellis Johnson and Manfred Padberg Awarded 1985 Dantzig Prize

The 1985 Dantzig Prize was awarded to **Ellis L. Johnson** and **Manfred W. Padberg** at the opening ceremonies of the Boston MPS Symposium.

The Dantzig Prize "is awarded jointly by the Mathematical Programming Society and the Society for Industrial and Applied Mathematics. The prize is awarded for original work which, by its breadth and scope, constitutes an outstanding contribution to the field of mathematical programming.... The contribution(s) for which the award is made must be publicly available and may belong to any aspect of mathematical programming in its broadest sense. The contributions eligible for consideration are not restricted with respect to the age or number of their authors although preference should be given to the singly-authored work of 'younger' people".

The first Dantzig Prize was awarded in 1982 jointly to M.J.D. Powell and R.T.

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Beck, Lenstra and Luks Receive Fulkerson Awards

The three recipients of the Fulkerson Prize awarded at the International Symposium at MIT in August were as follows:

- to **Jozsef Beck**, Mathematical Institute of the Hungarian Academy of Sciences, H-1395 Budapest, Pf. 428, Hungary, for the paper "Roth's Estimate of the Discrepancy of Integer Sequences is Nearly Sharp," *Combinatorica 1* (4) 319-325 (1981).

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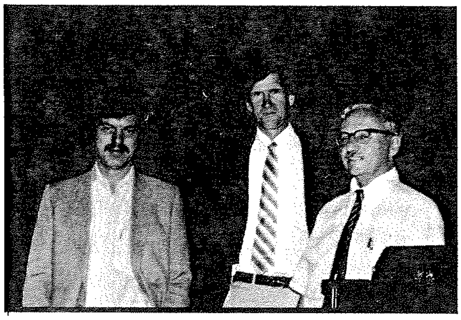


L to R: Manfred Padberg and Ellis Johnson with George Dantzig

Rockefellar. The 1985 Committee (G. Nemhauser, M. Balinski, M. Powell and R. Wets, chairman) formulated its recommendation in the following terms.

A rich variety of problems, including those of resource allocation, distribution, facility location, scheduling, production and reliability, can be formulated as discrete optimization models. Generally, these models involve a large number of variables and/or constraints. Although the models are very robust in the situations that they can describe, their efficient solution has proven to be a very difficult problem in computational mathematics. Only recently have the theory and computational aspects of the subject been synthesized to achieve algorithms that are capable of solving discrete optimization models of significant size and complexity. Johnson and Padberg, alone and together, have made major theoretical and computational contributions to the recent significant developments in discrete optimization and have applied their work to solve practical problems.

Modern integer programming began thirty years ago. In a seminal paper, Dantzig, Fulkerson and Johnson solved a 48-city traveling salesman problem by linear programming. Their essential idea was to use valid linear inequalities or cutting planes to cut off optimal fractional solutions to a linear programming relaxation of the traveling salesman problem. Their approach, however, was ad hoc. The method for generating valid inequalities was neither general nor automatic. The contribution was an idea rather than a general procedure and a demonstration that the idea could work.

In 1958, Gomory gave a finite cutting plane algorithm for the solution of integer programming problems. Here the cutting planes are automatically generated and it was shown constructively that the general integer programming problem can be solved as a finite sequence of linear programs. Unfortunately, Gomory's basic algorithm and some variations failed in practical computation because of extremely slow convergence. The reason for this is that the cutting planes used by the algorithm are weak. As a result, branch-and-bound algorithms became the main practical approach to solving, often approximately, integer programming problems. But, because of its enumerative character, the success with this approach has been unpredictable and the size of problems that can be solved is severely limited.

In 1965, Edmonds showed that a special integer programming problem, known as the matching problem, could be solved very efficiently using a linear inequality description of the convex hull of integral solutions. This approach has proven to be enormously valuable and seminal in the development of a literature known as polyhedral combinatorics. The main obstacle that prevents this approach from being applied to general integer programs, and most practically important special cases, is that an explicit linear inequality description of the convex hull of integral solutions is unknown and is unlikely to be found. Nevertheless, a significant effort has been made to identify and use facets (full dimensional faces) of the convex hull of feasible integer solutions to many problems, including set covering and packing problems, the knapsack problem, the traveling salesman problem, fixed-charge network problems and relaxations of the general integer programming problem. The basic idea is to design cutting plane algorithms that use strong cuts, frequently facets. The challenge is to characterize them and show how they can be automatically generated to render fractional points infeasible.

In this endeavor, Johnson and Padberg played central roles, Johnson primarily in his work on the group theoretic approach to the general integer programming problem (work begun by Gomory in the late 1960's), and Padberg primarily in his work on structured packing and covering problems and the traveling salesman problem.

Johnson, initially with Gomory, in a series of papers beginning in 1972, pursued the idea of generating facets of the convex hull of feasible solutions to the group-theoretic relaxation of an integer program, i.e., the so-called corner polyhedra. This is one of the most general family of polyhedra for which the convex hull of integral solutions has been characterized. He pioneered the use of subadditive functions in the generation of strong cutting planes. Several of his papers have significant computational experiments that demonstrate the efficiency of the algorithms. Johnson has also worked on a variety of combinatorial optimization problems including edge coloring, matching, chinese postman, scheduling and plant location. In 1966, he wrote a fundamental paper on labeling techniques for network flow problems that led to the data structures used in modern network flow codes. And while most of his research is in discrete optimization, he has also worked in inventory theory.

Padberg, on the other hand, began by focusing on special problems, especially packing and covering problems, and the traveling salesman problem. His main thrust has been the study of facets and their use in developing efficient algorithms. Beginning in 1972, he published a number of papers on the facial structure of set packing polyhedra. Alone, and in joint work with Grotschel and Rao, he has produced many results on the traveling salesman polytope. This work has been brought to fruition in two computational studies, one with Crowder and the other with Hong, in which they systematized the early work of Dantzig et al. on the traveling salesman problem by showing how to automate the generation of strong cutting planes. Their strong cutting plane/branch-and-bound algorithm has solved traveling salesman problems with up to 318 cities. Padberg, in joint work with Wolsey and others, has applied this approach successfully to fixed-charge flow problems. Padberg has also made significant contributions to the characterization of perfect graphs. In joint work with Rao, he has shown how the ellipsoid method can be used to obtain polynomial-time algorithms for combinatorial optimization problems. (These important results were obtained independently by Grotschel et al.)

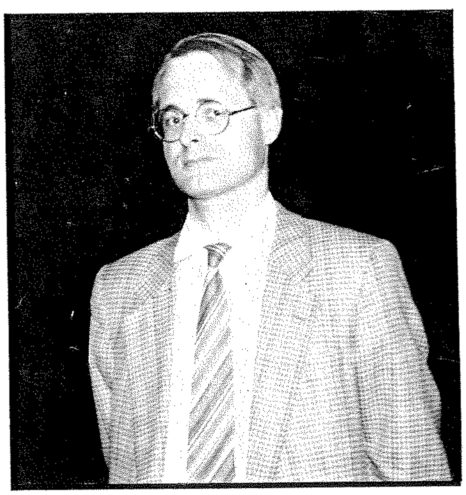
The major streams of Johnson's and Padberg's theoretical and computational work on strong cutting planes merged in their joint 1983 paper with Crowder. In it, the facets developed earlier for knapsack polytopes were linked with linear programming and branch-and-bound to produce the code for 0-1 integer programs known as PIPX. This code has solved large-scale, real-world, 0-1 problems with up to 2750 variables and represents state-of-the-art methodology for 0-1 integer programs.

The citation reads: "The 1985 George B. Dantzig Prize is awarded jointly to Ellis L. Johnson and Manfred W. Padberg. Both have made very significant contributions to the theory, computation and uses of discrete optimization. Beginning at different sources, Johnson with the group theoretic relaxation of integer programming, and Padberg with covering and packing problems and the traveling salesman problem, have initiated the strong cutting plane approach to solving integer programming problems. This work has produced a state-of-the-art algorithm for 0-1 integer programs and has also contributed substantially to the theory of integral polyhedra, i.e., the description (or partial description) of the convex hull of integral points by a set of linear inequalities. Each individually has made numerous contributions to graph theory, combinatorial optimization and applications of mathematical programming. Their overall research efforts have combined mathematical insight, computational development and application very much in the spirit of George Dantzig's approach and in the highest standards of mathematical programming."

–M. Balinski
R. Wets

Citation: In the cited paper Beck solves a long-standing problem of K.F. Roth by showing that the integers from *1* to *N* can be 2-colored so that in each arithmetic progression the numbers of red and blue points differ by less than $N^{1/4+\varepsilon}$. He proves this by deriving a general upper bound on the discrepancy of a family of sets, which is defined as the minimum, over all two-colorings of the elements, of the largest imbalance between the two colors in a set from the given family.

In further papers Beck solves problems raised by K.F. Roth, W.M. Schmidt and others. He determines with great precision the discrepancies of families defined by disks, rectangles and convex planar sets. His methods involve an ingenious combination of combinatorial arguments with methods from linear algebra, probability theory and Fourier analysis. The recent growing interest in combinatorial discrepancy theory has been inspired in large part by his work.



Fulkerson Awardee H.W. Lenstra Jr.. Jozsef Beck and Eugene Beck also received Fulkerson Awards (photos not available).

• to **H.W. Lenstra, Jr.**, Department of Mathematics, University of Amsterdam, Mathematisch Instituut, Roetersstraat 15, 1018 WB, Amsterdam, The Netherlands, for the paper "Integer Programming with a Fixed Number of Variables, *"Mathematics of Operations Research 8* (4), 538-548 (1983).

Citation: The main result of the cited paper is that the problem of integer linear programming can be solved in polynomial time if the number of variables is fixed. This theorem answers a long-standing open question. Of particular interest are the methods introduced by Lenstra in order to solve this problem. His algorithm is a combination of two important methods. First, he develops a technique which enables him to extract as much information from the set of real solutions of the program as necessary. This step is quite interesting from the point of view of convex analysis and is in a sense polar to the ellipsoid method. In the second phase of the algorithm, he takes integrality into account, using a "basis reduction" technique based on the geometry of numbers. This establishes a connection between integer programming and classical fields of number theory.

The result has already found many applications. It has been used to show that best simultaneous diophantine approximation for a fixed number of reals can be found in polynomial time. It was also used to break a version of the Merkle-Hellman cryptosystem. It has inspired a great deal of further research in the algorithmic theory of lattices of points, in diophantine approximation and in integer linear programming.

• to **Eugene M. Luks**, Department of Computer and Information Sciences, University of Oregon, Eugene, Oregon 97403, for the paper "Isomorphism of Graphs of Bounded Valence Can Be Tested in Polynomial Time," *Journal of Computer and System Sciences 25* (1) 42-65 (1982).

Citation: The problem of determining whether two graphs are isomorphic is one of the most fundamental problems in computational graph theory, and its computational complexity has attracted a great deal of interest. In the cited paper Luks provides a polynomial-time algorithm for the previously intractable case of bounded-degree graphs. Luks' method is to reduce this problem to the set stabilizer problem for certain permutation groups and then to introduce unexpectedly efficient divide-and-conquer methods to solve the problem for this class of groups. The links that Luks forged enabled deep methods from group theory to be applied to the graph isomorphism problem and inspired significant new research by Luks and others on the computational complexity of group-theoretic problems.

International Conference on Stochastic Programming Prague, Czechoslovakia September 15-19, 1986

This conference is being organized by the Faculty of Mathematics and Physics, Charles University Prague, cosponsored by the International Institute for Applied Systems Analysis, Laxenburg, and the Commitee for Stochastic Programming of the Mathematical Programming Society. The preregistration should be mailed to the following address by December 15, 1985:

Dr. Tomas Cipra
Dept. of Statistics
Sokolowska 83
18600 Prague 8
Czechoslovakia

–Jitka Dupacova

Joint US/FRG Seminar Applications of Combinatorial Methods in Mathematical Programming Gainesville, Florida March 18-22, 1985

Many areas of Mathematical Programming use methods developed in the field of combinatorics. The purpose of this conference, organized by A. Bachem (Koeln) and H. Hamacher (Gainesville), was to bring together leading experts of the United States and the Federal Republic of Germany to discuss modern trends and new results in combinatorics. There were also participating researchers from six non-US/FRG countries.

The topics discussed included the analysis of NP-complete problems and data structures for polynomially solvable problems, investigations of combinatorial structures and the modelling of real world problems. A large portion of the conference was devoted to discussions of open problems which were provided by every participant. Abstracts and open problems are published as reports of the Department of Industrial and Systems Engineering, University of Florida, and the Department of Mathematics, University of Koeln, and are available upon request.

The social program included a reception, with a welcoming speech by the President of the University of Florida, and a hike.

-H. Hamacher

14th International Symposium on Mathematical Programming 1991

The Mathematical Programming Society is seeking a host for its International Symposium in 1991. For information please contact the chairman of the Symposium Advisory Committee by mail or phone as follows:

M. Grotschel
Institute f . Mathematik
Univ. Augsburg
Memminger Str. 6
D-8900 Augsburg
W. Germany
Phone: (0821) 598-317

Call for Papers

Optimization Days 1986 April 30 - May 2, 1986 Montreal, Canada

OPTIMIZATION DAYS 1986 will be held at Ecole des Hautes Etudes Commerciales de Montreal (Graduate Business School of the University of Montreal) from April 30 to May 2, 1986.

The topics include all aspects of optimization theory and applications. Contributed papers should be sent before January 31, 1986 to:

Alain Haurie
Director of GERAD
Ecole des H.E.C.
5255 avenue Decelles
Montreal (Quebec) H3T 1V6
Tel: (514) 340-6042

New Doctoral Program Offered

European Doctoral Program in Quantitative Methods in Management – A Joint Program

The Universite Paris-Dauphine, Erasmus Universiteit Rotterdam and Universite Catholique de Louvain have set up a coordinated doctoral program in quantitative methods in management. Each student will be registered in a doctoral program of one of the universities and will typically spend the second year of his doctoral studies at one of the other two.

The program is aimed at a limited number of highly qualified students with a fundamental interest in management and a good background in quantitative methods.

Further information about the program can be obtained from:

Professor J.M. Lasry, UER Mathematiques de la Decision, Universite Paris IX, Place Marechal de Lattre de Tassigny, F-75775 Paris, Cedex 16, France.

Professor A.H.G. Rinnooy Kan, Econometric Institute, Erasmus University, P.O. Box 1738, 3000 DR Rotterdam, The Netherlands.

Professor L.A. Wolsey, Industrial Engineering, CORE, Professor Ch. Delporte, School of Management, IAG, Universite Catholique de Louvain, B-1348 Louvain-La-Neuve, Belgium.

–L. Wolsey

Applications of Nonlinear Programming to Optimization and Control
Edited by H.E. Rauch
Pergamon Press, Oxford
1984
ISBN 0-08-030574-1

This is a very nice collection of interesting papers on the application of Nonlinear Programming Methods to Practical Control Problems.

These papers were presented at the 4th IFAC Workshop in San Francisco, which was organized by the editor on June 20-21, 1983. The members of the corresponding Program Committee were Professors **Arthur Bryson, Jr.** (U.S.A.), **H.T. Banks** (U.S.A.), **Phillip Gil** (U.S.A.), **Faina M. Kirillova** (U.S.S.R.), **R.W.H. Sargent** (Great Britain) and **J.P. Yvon** (France).

This volume contains contributions of 17 international experts who presented their latest work in this field. The papers cover a wide range of research topics starting with Computer Aided Design of Practical Control Systems, continuing through advanced work on quasi-Newton methods and gradient restoration algorithms and culminating with specific examples which apply these methods to representative problems. Many examples are presented.

Study of these papers is highly recommended. This book is an essential contribution for the application of nonlinear programming methods to modern practical control problems.

-D. Pallaschke

Algebraic and Combinatorial Methods in Operations Research
Edited by R.E. Burkard, R.A. Cunninghame-Green, and U.Z. Zimmermann
North-Holland, Amsterdam
1984
ISBN 0-444-87571-9

In recent years various methods have been applied to describe and solve discrete optimization problems. For example, by choosing the cost coefficients as elements of an ordered algebraic structure, a unification and generalization of various problems (including sum, bottleneck and lexicographical objectives) can be achieved. Another example provides the max-min algebra which leads to applications in scheduling and fuzzy equations. A workshop in Bad Honnef, April 1982, brought together for the first time researchers from different countries to discuss the applications of algebraic methods to Operations Research problems. The volume contains 20 selected contributions to this workshop.

The papers contain original work and can be grouped as follows:

Several contributions consider algebraic flow problems proving general max flow-min cut theorems. Also algorithms to solve the algebraic flow problems are given.

Another group of papers deals with new results on matroids, matroid intersections and the Greedy Algorithm. In particular, new results on perfect independence systems and matroids on ordered ground sets are presented.

Several papers investigate algebraic linear programs. In one a dual optimality criterion is generalized; another paper exploits solution properties of extremal linear programs.

Two papers investigate graph problems. The shortest path problem on signed graphs is considered. The other paper investigates relations between pseudo Boolean functions and the stability number of graphs.

Also included is a thorough investigation of the relationship between substitution decomposition known for Boolean functions, set systems and relations as applied to optimization problems. A survey paper provides recent results of the french school on computations in dioids.

Finally, new applications of the algebraic approach are also presented. One paper deals with a fire protection problem; another considers scheduling problems using non-commutative algebra.

To summarize, the contributions in the book give insight into the state of the art of the algebraic side of combinatorial optimization. The book is recommended to anyone interested in recent trends in discrete optimization.

-F. Rendl

Optimization Theory and Applications
by Jochen Werner
Vieweg, Wiebaden
1984
ISBN 3-528-08594-0

The book gives a nice introduction to the foundations of optimization theory and its applications. It is the refined and enlarged version of the manuscript of a course the author gave at the University of Gottingen. This origin of the book strongly influences the lively style of the presentation. A number of accompanying examples, to which the author refers throughout, serve as a permanent stimulation. The book can be recommended either for self-study or as a textbook for an introductory course in optimization.

The book is self-contained and does not require more than elementary knowledge from a first course on algebra and analysis. All tools from functional analysis needed in the text (like separation theorems) are developed in the book. The most important aspects of the course are the duality theory for convex programming and necessary optimality conditions for nonlinear optimization problems in infinite-dimensional spaces. No numerical methods are discussed; however, it is made clear that many of the results presented are fundamental for algorithms that are applied in practice to the numerical solution of optimization problems.

After some examples in Chapter 1, the classical duality theory for finite-dimensional linear programming problems is developed (Chapter 2); the approach stresses the geometrical background. Chapter 3 provides some tools from functional analysis which are used in Chapters 4 and 5 to discuss the main results in convex and in differentiable optimization in normed linear spaces. The classical optimality conditions are derived and applied to a number of control and approximation problems.

–Jochem Zowe

Sensitivity, Stability and Parametric Analysis
Mathematical Programming Study 21
Edited by A.V. Fiacco
North Holland, Amsterdam
1984

Several years ago the editor, Prof. A.V. Fiacco, had a splendid idea, to organize yearly a special conference on Mathematical Programming with Data Perturbations. These conferences have been highly acknowledged by specialists the world over and the corresponding proceedings have sold well.

Fiacco organized and edited this Mathematical Programming Study which is devoted to stability analysis and parametric programming as well as to mathematical programming with data perturbations. It shows convincingly that sensitivity analysis, parametric programming, mathematical programming with data perturbations, for which there is no specialized Journal or no SIG, comprise a branch of operations research which can no longer be overlooked.

This book can be recommended to all scientists working in the area of the theory of linear and nonlinear programming, in perturbation analysis, to specialists working in the area of inventing new methods for solving nonlinear programs, and to students of OR.

–T. Gal

Data Structures and Algorithms
Volumes I, II and III
By Kurt Mehlhorn
Springer Verlag, Berlin
1984

During the last decade considerable progress has been made in the area of data structures and efficient algorithms. Many of the recent inventions, e.g. randomized algorithms, new methods for proving lower bounds or new data structures for weighted dynamic data, have never appeared in book form before.

The author's work is split into three volumes. Volume I starts with a thorough treatment of different basic models of computation and introduces most of the commonly used data structures. The very precise presentation is accompanied by an easily understood intuitive description in order to enable the nonexpert to capture the basic ideas. Following the introductory section, various sorting algorithms are treated extensively and lower bounds for the sorting problem are derived. Together with somewhat more sophisticated data structures, the results are used to obtain efficient methods for one-dimensional searching. The great effort spent on discussing sorting problems is justified by its practical importance: As the author remarks, an IBM estimate claims that sorting consumes about 25% of the total computing time spent by commercial codes.

Volume II is about Graph Algorithms. The author discusses how graphs can be represented in a computer and treats different methods for exploiting a graph (such as depth first and breadth first search). He intends to explain the principles of how to deal with graphs from a computational point of view and therefore restricts himself to considering only those problems which are quite "simple" from a theoretical point of view. For example, the matching problem is treated for bipartite graphs only. A considerable part is devoted to developing the relationship between path problems in graphs and matrix multiplication. The last chapter of this book is an excellent introduction to the theory of NP-completeness.

Volume III starts with considering multidimensional search problems. d-dimensional search trees are shown to be, in a sense, the optimal data structures for this kind of problem. General principles are described which might be used to overcome in part the problem of balancing multidimensional search trees. The major part of this volume is devoted to computational geometry, which deals with the problem of determining the intersection of geometric objects such as lines or polygons in the plane. Many logarithmic algorithms are developed to solve these problems.

The material covered in this book leads the reader from the basics to current research. The presentation is very clear and everything is developed in a straightforward manner. For those who are familiar with the fundamentals of data structures, such as queues, stacks and linked lists, volumes II and III are recommended separately.

–W. Kern

Algebraic and Geometric Combinatorics
Annals of Discrete Mathematics Vol. 15
Edited by Eric Mendelsohn
North Holland, Amsterdam
1982
ISBN 0444-86365-6

The theories of designs, graphs, latin squares, finite groups, geometries and lattices, which represent the main subjects treated in this volume, constitute cornerstones of combinatorial methematics. The papers on design theory deal with the construction of block designs, the study of Steiner systems and their generalizations, or the enumeration of special types of designs. The hamiltonicity of metacirculant graphs, studies of rigid as well as distance regular graphs, and two new proofs of the Mendelsohn-Dulmage theorem, one within the framework of linear inequalities, are the contents of the graph-theoretical papers. Two classical problems related to latin squares are the establishment of necessary and sufficient conditions for the completeability of incomplete latin squares and the existence of special types of latin squares. Of particular interest are implications for timetabling (here "match-tabling") and, more theoretically, the treatment within universal algebra or the field of finite groups and geometries. Within this latter area a study of the product of all elements in a finite group, a discussion of finite fields from a combinatorial point of view, incidence-geometric aspects of finite abelian groups and the construction of special partial geometries are presented. The concept of lattice polyhedra finally has proven to be very suitable in embracing various results from polyhedral combinatorics. Properties, constructions and examples for such polyhedra are the subject of a first contribution within lattice theory. A second paper displays the use and appeal of lattice diagrams.

This book is more than just a collection of papers. It is the presentation of interrelations between several branches of combinatorics which makes it interesting to read. It also reflects the strong influence on the development of algebraic and geometric combinatorics of Prof. Nathan Mendelsohn, to whom this book has been dedicated on the occasion of his 65th birthday.

–Reinhardt Euler

Combinatorial Algorithms
by T.C. Hu
Addison-Wesley, New York
1982
ISBN 0-201-03859-5

The author opens by stating his intent to present "some combinatorial algorithms" common to computer science and operations research. His final remark is, "Hopefully, this book will arouse interest in combinatorial algorithms." He succeeds in providing a readable, interesting account of some combinatorial algorithms.

The informal development and motivation can be enjoyable as well as useful as a pedagogical aid. The presentation style uses illustrative examples instead of general descriptions. On the topics covered, bibliographical notes and references are provided.

The author dispenses with the usual onslaught of definitions of terms and notation. Consequently, he relies in part on the reader's intuition and tolerance of imprecision, which could be frustrating to the beginner. (For example, a *path* is defined as a directed path and then is later allowed to have reverse arcs.)

The book begins with a complete treatment of the shortest path problem. The next topic covered is the maximum flow problem, where the max-flow-min-cut theorem is presented and several methods of computing a maximal flow as part of the Ford-Fulkerson algorithm are described. A scant treatment of the minimum cost flow problem is provided. Considerable attention is paid to the problems of realization, analysis, and synthesis of multiterminal maximum flow problems, PERT, and the optimum communication spanning tree problem. Dynamic programming is discussed, illustrated by the shortest path problem, the knapsack problem, and the minimum cost alphabetic tree problem. Backtracking and branch and bound are presented and illustrated, followed by algorithms for construction of binary trees of minimum weighted path length and optimal alphabetic trees. Heuristic algorithms are given for the coin changing problem, bin packing, job scheduling, and partitioning a convex polygon into triangles. The book concludes with a chapter on complexity theory, including a brief guide to facing new combinatorial problems.

With an informal treatment of selected topics, this book gives the reader a taste of the field of combinatorial algorithms.

-C.R. Coullard

Linear Programming
by V. Chvatal
Freemann, New York
1983
ISBN 0-7167-1195-8

It has been my opinion that, in spite of a plethora of books on the subject, the best of the textbooks in linear programming written in the early sixties was not significantly improved upon in the succeeding 20 years. Obviously, a quantum leap in quality was inevitable. It has come with this brilliant new exposition of Chvatal.

This book is exceptionally well written. Few authors can write this well, and of those who can, fewer take the trouble. The author is to be commended for the obvious pains he has taken in attention to detail and style. It is most apparent in the background chapter on linear algebra, in numerous references explaining historical aspects, and in careful and complete presentations of advanced topics like modern basis factorizations and the ellipsoid method.

An interesting aspect of the book is that, while ultimately quite sophisticated, it is completely self-contained. The book assumes no linear algebra, presenting most of the basic ideas and theory of the simplex method and duality from scratch in the first five chapters. Proofs are algebraic and constructive in spirit. There is no use, even for motivation, of either geometry or convexity.

Chapter Six, Gaussian Elimination and Matrices, is a tour de force of linear algebra, in preparation for the introduction of the revised simplex method. A reader who does come to this book with no linear algebra background will have to take this chapter slowly, but it is complete, covering precisely the right topics with the right emphases. On the other hand, more sophisticated readers will still learn a lot from this chapter. I did, and I suspect that authors of the current crop of linear algebra texts would also.

Chvatal's treatment of the revised simplex method is based on keeping the basis as a product of eta matrices, plus periodic refactorization into triangular factors. The author does an excellent job of presenting the methods and explaining why the typical sparse structure of problems solved in practice dictates these strategies. The remainder of this first section extends previous results to more general forms of linear programs and treats sensitivity analysis, incluing the dual simplex method.

The second section, Selected Applications, ranges from concrete elementary applications like allocation of resources through the cutting stock problem and matrix games to theoretical chapters on systems of inequalities and geometry. In the latter chapters linear programming is used in an elegant way to derive deep and beautiful mathematical results.

The third section is on network flow problems. Here another huge improvement on standard presentations is evident. The network simplex method is described in a way that is at once more general, more direct, and closer to modern computer implementations than those in the standard textbooks. (Can we hope that we have finally seen the last of transportation tableaux?) It is incredible to me that this algorithm, arguably the most important in all of combinatorial optimization, is not even described in some books on that subject. This section gives a number of nice combinatorial applications of the network simplex method as well as describing the "labelling methods." While the latter are well done and completely up to date, to me their inclusion seems unnecessary.

The last section is on advanced techniques, including more sophisticated methods for the revised simplex method, and describes generalized upper bounding and Dantzig-Wolfe decomposition. Again, the presentations are not standard and are very well done. An appendix describes the ellipsoid method explaining the theory as well as placing it in an historical and practical perspective.

This book is not easy to criticize. I was a little disappointed and surprised that the author did not find occasion to introduce some integer programming and cutting planes somewhere, especially given his own research interests. As for errors, they seem hard to find; I can report three. On page 113 "revised simplex method" should read "standard simplex method." On page 400 the attribution to Munkres of an $O(n^3)$ assignment algorithm is not accurate. Finally, not all of the exercise solutions on page 466 are correct.

-W.H. Cunningham

Technical Reports & Working Papers

Stichting Mathematisch Centrum
Centrum voor Wiskunde en Informatica
Postbus 4079 1009 AB Amsterdam
Kruislaan 413 1098 SJ Amsterdam

J. K. Linstra and A.H.G. Rinnooy Kan, *"New Directions in Scheduling Theory,"* OS-R8401.

J.P.C. Blanc, *"Asymptotic Analysis of a Queueing System with a Two-Dimensional State Space,"* OS-R8402.

J. Han and M. Yue, *"A Study of Elimination Conditions for the Permutation Flow-Shop Sequencing Problems,"* OS-R8403.

J.H. van Schuppen, *"Overload Control for an SPC Telephone Exchange: An Optimal Stochastic Control Approach,"* OS-R8404.

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Founding father or just a footnote?

by David Warsh, Globe Staff
Reprinted by permission from *Boston Globe*, Aug. 9, 1985

Last fall, a spate of news reports appeared–including one on the front page of the *New York Times*-- reporting that a Bell Laboratories scientist named Narendra Karmarkar had discovered a much faster way to solve difficult planning problems on computers.

This week in Cambridge, the 28-year-old Karmarkar came under mounting fire from his colleagues at the 12th International Symposium on Mathematical Programming. They snorted at his scientific manners, scoffed at his claims and derided his results as being everything from "frisky" to "majestic." Mostly, they said that his accounts of super-fast solutions to difficult problems couldn't be replicated.

"My algebra is a lot slower than Narendra Karmarkar's, I join the general chorus on that one," said David M. Gay of Bell Labs. "He may have some wonderful method after all, but I habitually mistrust all secret mathematics," said E.M.L. Beale, a pioneer in the commercial applications of linear programming.

The practical applications of the new algorithm (a mathematical procedure used mainly with computers) to a wide range of problems was thus generally judged to be still an open question – nearly two years after it was first broached within the programming community.

Karmarkar's discovery initially had been billed as a scientific breakthrough of major proportions, and perhaps a commercial coup too. A significantly better way to make decisions about scheduling airplanes, mixing ingredients, cutting steel, routing telephone calls and such other archetypical tasks of the modern world could be worth many millions of dollars.

The news was all the more remarkable since, on problems with large numbers of variables, Karmarkar's algorithm was said to outperform one of the most durable intellectual attainments of fast-moving 20th century applied math, the simplex method of linear programming which has gone hand and glove with computers for planning purposes since its invention 38 years ago.

Among mathematical programmers – the scientists who preside over the marriage of mathematics and computers – the news of the breakthrough was met with a certain skepticism. They quickly went to work examining the method, and since then, hopes have dimmed, disappointment has grown and an undertone of puzzlement and even rancor directed at Bell Labs has crept into the discussion.

Increasingly, the verdict has been that Karmarkar's new approach to linear programming, while interesting and thought-provoking, may have its roots in old, well-understood alternatives, and that its applications may be less broad than had been hoped.

It doesn't help that a similar claim five years ago by a Russian researcher seemed promising initially, and turned out to be theoretically elegant, but didn't pan out as practical.

Karmarkar himself didn't advance his cause much in a talk before an unusual plenary session of the MIT meeting of some 800 scientists from around the world. He began by observing that while mathematicians agree on what constitutes convincing proof of a mathematical proposition, there is no corresponding consensus as to what makes a persuasive presentation of experimental results - a contention that was immediately disputed by many of his listeners.

He again reported having achieved extremely fast and accurate numerical solutions – 30, 40, 50 times faster than present methods – to complex planning problems that had been posed to him by others. But several times when pressed for details, he refused to supply them, saying they were proprietary. He declined to give colleagues copies of the transparencies that he quickly slipped on and off a projector to illustrate his 40-minute talk.

And at another juncture, as he presented his evidence of the superiority of his method to the simplex algorithm, he simply omitted from his table of results the two hardest problems in a set of 17 - without mentioning what he had done. His rival colleagues glared in disblief.

Later, in an interview, Karmarkar said the disagreements arose because his critics were simply not doing their homework. He said he left out the results of the two sample problems because he felt they were not commensurable or compatible with those others were using.

"I think that it is clear from what we know that we can rule out scientific fraud," said Jeremy F. Shapiro of MIT, the program chairman of the symposium, "but there has been less than full disclosure."

Michael Garey, Karmarkar's department head at Bell Labs, said, "Narendra's like that. It took me three months to get his viewgraphs from the last talk. He doesn't pay much attention to building his political base in this kind of thing."

The situation is complicated by the possibility that Karmarkar's algorithm is commercially valuable. IBM Corp. sells a package of simplex computer codes for $1,200 a month to hundreds of corporate customers who use them for everything from scheduling traveling salesmen to deciding what timber to harvest. Karmarkar has frequently claimed that his method worked 50 times faster than IBM's on big problems with many variables.

"People have a heavy investment, both intellectual and financial, in the simplex method," Karmarkar said.

Despite the criticism, some of Karmarkar's colleagues stressed that the scientist's basic insight was sound. The mere fact that so many sessions at the five-day symposium were devoted to an examination of his method testified to the usefulness of the exercise he had triggered, they said.

"There has been a careful reexamination of what it is we have been doing for 38 years as a result," said Beale.

Some researchers said they still felt that it was likely that Karmarkar was onto something important, even if incontrovertible proof hadn't been furnished. Michael J. Todd, of Cornell University, for example, said that he thought that Karmarkar would be vindicated in the long run: "He knows his stuff better than most: computer architecture is going to change."

If the controversy surrounding the Karmarkar algorithm dominated the main ring, there was much else going on, most

continued on next page

of it under the rubric of parallel processing. Indeed, the commotion all but eclipsed the news of a remarkable result by Victor Pan and John Rief, of the State University of New York at Albany and Harvard University, respectively.

They, too, have a new way of achieving dramatic computational speed-ups. Theirs involves solving large numbers of linear equations by computer – one that promises application to a wide range of practical problems as quickly as parallel processing computers can be built.

"These are very exciting times," said George Dantzig, the inventor of the simplex method, who was honored at a dinner celebrating his 70th birthday. "I'd swap 20 years with any of you for the chance to compete in the present situation."

New Editor-in-Chief *From page 1*

subject matter." As such, it may treat an area that is not emphasized by the Journal, thereby broadening the horizon of our regular readers. But the Studies are hampered by a limited distribution and an irregular appearance. The current supply of material for the Studies motivates a discussion of various possibilities to strengthen the identity of the series. This is very much an open issue. The Publications Committee welcomes any ideas and suggestions on this matter.

The other editors serving the Journal and the Studies, including the Senior Editors, will be invited to resign in deference to the new Editor-in-Chief; all new appointments are in his domain. This is to some extent a formality, and Dick and Mike will work out a smooth transition.

The number of free reprints of papers provided to authors will be increased from thirty to fifty, at a moderate cost for the Society.

With respect to the *COAL Newsletter*, Jan Telgen resigned as Editor. Robert R. Meyer will continue in this position and seek a European Co-Editor. Since the Bonn Symposium, *Optima* has been expanded by the useful addition of book reviews. On the other hand, it remains difficult for Don Hearn and Achim Bachem to obtain feature articles (in spite of the financial rewards that await prospective authors).

The new Publication Committee will consist of Richard W. Cottle, Martin Grotschel, and Jan Karel Lenstra (chairman). We would be pleased to receive your comments on the publications of the Society.

-Jan Karel Lenstra

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Narendra Karmarkar (AT&Y Bell Labs) received the ORSA Lanchester Prize at the November ORSA/TIMS meeting at Atlanta...The November SIAM Newsletter features three articles on the Karmarkar algorithm and its reception...The ISI announces Competitions for Young Statisticians in Developing Countries. Contact the ISI at 428 Prinses Beatrixlaan, 2270 AZ Voorburg, The Netherlands...The Third SIAM Conference on Discrete Mathematics will be held May 14-16, 1986 at Clemson University. Contact SIAM Coordinator, 117 South 17th St., 14th Floor, Philadelphia, PA 19103-5052...**George Dantzig** was a recipient of the 1985 Harvey Prize of the Technion at the Institute's Haifa, Israel, campus on June 19...**George Nemhauser** has been named the Leon C. Welch Professor of Engineering at Cornell. He is currently visiting Ga. Tech. as Chandler Professor...**Bobby Schnabel** and **Paul Boggs** (NBS) have been organizing a SIAM Activity Group (SIAG) on Optimization. Contact Schnabel at Computer Science Department, University of Colorado, Boulder, Colorado 80309...**Mike Grigoriadis** reports that 90% of MPS dues are allocated to publications. This information is required by those charging memberships to Federal grants...An International Conference on Systems Science will be held in Poland, Sept. 16-19, 1986. Contact Jerzy Swiatek, Technical Univ. of Wroclaw, Janiszewskiego St. 11/17, 50-370 Wroclaw, Poland.

Deadline for the next OPTIMA is April 1, 1986.

Results of the MPS Election

The MPS Secretariat (at the International Statistical Institute) has reported the results of the recent Council elections. Noting the special features of the terms of office of chairman, vice-chairman, and treasurer, the incoming Council will be:

Aug. 1985 - Aug. 1986: Chairman, Alex Orden, Vice-Chairman, Michel Balinski; Aug. 1986 - Aug. 1988: Chairman, Michel Balinski, Vice-Chairman, Alex Orden; Treasurer, Al Williams, whose present term of office runs until 1986. Elected to another term: Aug. 1986 - Aug. 1989.

Aug. 1985 - Aug. 1988: Members-at-Large: Martin Grotschel, Masao Iri, Karla Hoffman, Robert Schnabel.

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

Journal contents are subject to change by the publisher.

Donald W. Hearn, Editor
Achim Bachem, Associate Editor
Published by the Mathematical Programming Society and Publication Services of the College of Engineering, University of Florida.
Composition by Lessie McKoy,
Graphics by Lise Drake.

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