OPTIMA

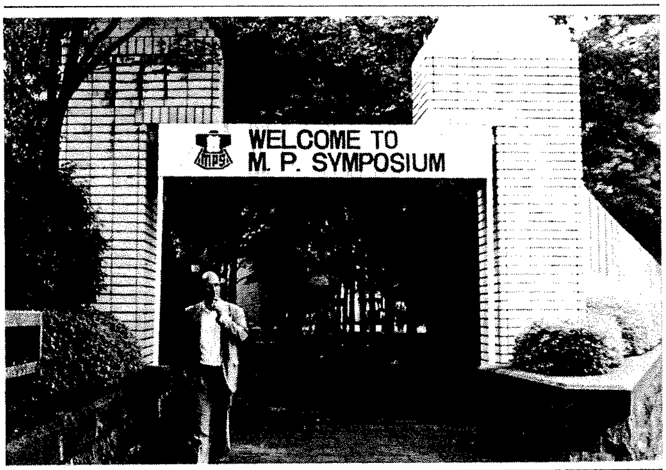
№ 25

MATHEMATICAL PROGRAMMING SOCIETY NEWSLETTER

NOVEMBER 1988

# *Tokyo Symposium Report*

THE first MPS meeting in Asia proved to be a big success with 668 mathematical programmers from 36 countries attending the 13th International Symposium at Chuo University, Tokyo, August 28 through September 2. The meeting was jointly sponsored by the Operations Research Society of Japan, Hidinori Morimura, President, with cosponsorship by the International Federation of Operational Research Societies (IFORS), the Asian-Pacific Operational Research Societies, and several domestic societies. The organizing committee headed by Masao Iri, Hiroshi Konno and Kaoru Tone drew high praise for the smoothly-run technical and social programs.




MPS Chairman Michel Balinski addressed the membership at the opening session on Monday which also featured the awarding of prizes and a plenary lecture by Dantzig Prize recipient Michael Todd (Cornell). Fulkerson Prizes went to Éva Tardos (MIT and Eötvös Univ.) for her development of strongly-polynomial algorithms for the minimum cost flow problem and Narendra Karmarkar (AT&T Bell Labs) for his breakthrough work on interior methods for linear programming. The second Orchard-Hays prize was awarded to Tony J. Van Roy (Bank Brussels Lambert) and Laurence

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## Tokyo Symposium Report

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Wolsey (Universite Catholique de Louvain) for their work on automatic reformulation of mixed integer programs. The first A. V. Tucker Student Prize went to Andrew V. Goldberg (Stanford) for his MIT doctoral thesis entitled "Efficient Graph Algorithms for Sequential and Parallel Computers." (See accompanying articles.)

The scientific program consisted of 557 presentations in 185 sessions including seven tutorial/survey sessions, one special session for prize recipients, and two memorial lectures honoring Martin Beale and L. V. Kantorovich. The Beale lecture was given by John Tomlin (Ketron), and I. V. Romanovskii (Leningrad Univ.) delivered the lecture honoring Kantorovich.

Publications from the meeting will include a conference proceedings of principal lectures and a special issue of Mathematical Programming, Series B, containing high-quality application papers selected from those presented at the Symposium.

At the General Assembly on Thursday it was announced that Robert E. Bixby (Rice) will be the new editor of Mathematical Programming Series A beginning in mid-1989 and that W. R. Pulleyblank (Waterloo) is the first editor of Series B, which replaces the Studies series. Also, Karla Hoffman (George Mason) announced plans for a membership drive; the Committee on Algorithms announced that Faiz Al-Khayyal (Ga. Tech.) will be the new US co-editor of the COAL newsletter; and Jan Karel Lenstra announced that the 14th Symposium will be held in Amsterdam in 1991.

The social program included a welcoming reception on Monday evening at the Symposium site and a lavish Official Banquet on Wednesday evening at the famous Chinzan-so Restaurant and gardens, a tranquil island in the center of busy Tokyo.

## Tutorials and Survey Lectures at MPS Symposium

**Below is a list of the tutorial and survey lectures given at the Tokyo meeting:**

Thomas L. Magnanti ***Mathematical Programming and Network Design***

Michael Florian ***Mathematical Programming Applications in National, Regional and Urban Planning***

Andreas Griewank ***Automatic Differentiation***

Bernhard Korte ***Applications of Combinatorial Optimization***

Robert B. Schnabel ***Sequential and Parallel Methods for Local and Global Unconstrained Optimization***

Philip E. Gill ***Nonlinear Programming***

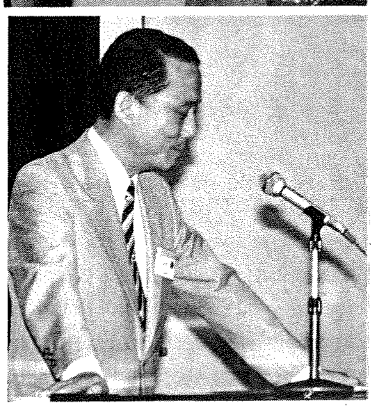
Freerk Auke Lootsma ***Multi-Objective Programming***

Krzysztof C. Kiewiel ***Nondifferentiable Optimization***

Roger J-B Wets ***Stochastic Programming: State-of-the-Art Survey***

Yoshitsugu Yamamoto ***Fixed Point Algorithms for Stationary Point Problems***

Laszlo Lovasz ***Recent Development of Number Theory and its Applications***



ABOVE LEFT: INCOMING MPS CHAIRMAN GEORGE NEMHAUSER AND GEORGE DANTZIG CELEBRATE AT BANQUET. RIGHT: MPS CHAIRMAN MICHEL BALINSKI. BELOW: SYMPOSIUM CHAIRMAN MASAO IRI

# Opening Address of the Chairman, Mathematical Programming Society

## *13th Symposium on Mathematical Programming, Tokyo, Japan, August 29, 1988*

The First International Symposium of our community, now organized and called the Mathematical Programming Society, bore the number 0 and was held in Chicago in 1949. Today, 39 years later, after eight symposia in the United States and one each in the United Kingdom, the Netherlands, Hungary, Canada and the Federal Republic of Germany, we begin the thirteenth here in Japan.

What are we? What is the nature of the intellectual endeavor in which we are engaged?

In 1946, at the first post-war international gathering of mathematicians held at Princeton[1], Herman Weyl railed against a prescription offered years before by Minkowski, which was: "... to face problems with a minimum of blind calculation, a maximum of seeing thought." He proffered a counter recipe in the following words, "I find the present state of mathematics, that has arisen by going full speed ahead under this slogan, so alarming that I propose another principle: whenever you can settle a question by explicit construction, be not satisfied with purely existential arguments." Fifteen years before Weyl had expressed his fears that the mathematical *substance* in the formulization of which mathematicians had exercised their powers showed signs of exhaustion. By 1946 he saw some hope but "... the deeper one drives the spade the harder the digging gets; maybe it has become too hard for us unless we are given outside help be it even by such devilish devices as high-speed computing machines."

We have those devilish devices. They have helped considerably. But the problem remains and will forever recur. The need to keep our ship afloat maintaining theoretical depth yet steering it with empirical demands and practical uses, remains and must forever remain a paramount concern. As Karl Marx so aptly said (at the tender age of 17), "And so we must be on guard against allowing ourselves to fall victim to that most dangerous of all temptations: the fascination of abstract thought."

As evidence of the power avoiding that temptation, it is fitting for me to recall two outstanding members of our community who have died since our last Symposium and whose memories will be celebrated in special sessions this week: Martin Beale and Leonid Kantorovich. They offer striking contrasts, yet remarkable similarities, and they were both central to mathematical programming.

Martin Beale's distinctive flavor was his untiring devotion to making mathematical programming work in practice: he made contributions to theory but more important he brought an exceptional insight and flair and insistence to modelling problems, implementing algorithms, developing systems for honest-to-God users. He came from a peculiarly British - some might say Cambridge - mathematical tradition that emphasized what I would call engineering analysis, not topology or algebra. He was, to borrow a phrase, the outstanding mathematical programming "numbers engineer".

Leonid Kantorovich, on the other hand, issued from the continental school with its deep roots in the traditional areas of mathematical analysis. A prolific mathematician with far-ranging interests, named a full professor in his early twenties, his fundamental contributions to functional analysis are considered by many his outstanding contribution. But motivated by economic problems he was led to linear programming and to interpretations of duality that were not well received in Stalin's Russia. And yet this may well have led to this study of the Monge-Kantorovich problem, to his formulations of duality in infinite programming, and the important results in probability that were obtained by him and his collaborators and which are still a major area of research. Indeed, as his wife stated at the Beale Memorial Conference one year ago, only now have many of his ideas in economics been finally accepted in his country, too late for him to know. So, he was an applied man in another sense, not numbers, but practical economic theory having important real implications.

Both men mixed theory with engineering, or mathematics with computation, or modelling with interpretation; their inspirations and motivations came from spheres other than mere mathematics; and this I believe is central to the intellectual endeavor of our subject. It seems that this mix of concerns is very well represented at this Symposium, perhaps better than ever before, although it is a pity that so few economists are now involved as versus their heavy participation in the early years. They do, after all, need help!

It is my hope that a more thorough blend, a more precarious balance on the razor's edge between theory and use and computation, will be realized by our journal in Series A and B and in the activities of a growing membership in our Society, and I cannot but hold up for all to see the examples set by Kantorovich and Beale.

We honor in them a Russian and an Englishman, and this first Symposium in the Far East (as versus what may well be the Far West in the eyes of our hosts) underlines the universal nature of our endeavors and the international cast of characters that are involved. It is my hope that an increasingly more thorough blend of nationalities will be represented in our Society, with the enhanced participation of the relatively underrepresented Asian nations, and in particular, those of the large nations of China, Japan and the U.S.S.R.

**–Michel L. Balinski**

[1] *The Princton University Bicentennial Conference on the Problems of Mathematics*, Princeton, NJ, 1946.

Tokyo Symposium Report

# *Prizes and Awards*

## Andrew Goldberg Awarded Tucker Prize

HAROLD KUHN PRESENTS TUCKER PRIZE TO ANDREW GOLDBERG

As the first recipient of the A. W. Tucker Student Prize, the Award Committee has chosen Andrew Vladislav Goldberg for his doctoral thesis at MIT, completed in January 1987, and entitled "Efficient Graph Algorithms for Sequential and Parallel Computers."

The committee found his work to be a deep and impressive contribution to the literature. His algorithms or extensions of his algorithms for the maximum flow problem and for the minimum cost flow problem are the best in terms of worst case complexity. Goldberg's work on parallel algorithms is also very important. Both his contributions to treatments of network flows and to "symmetry breaking techniques" are improvements on previous results in terms of worst case complexity for parallel algorithms.

*The A. W. Tucker Prize*, established in 1985, and awarded for the first time at the Tokyo Symposium, is for the outstanding paper by a student. The paper must be solely authored and completed since the beginning of the calendar year of the preceding Symposium. The paper and the work on which it is based should have been undertaken and completed in conjunction with a degree program.

Professor Tucker's contributions to our field have been outstanding. These contributions have come not only in the form of fundamental research but, in a very substantial way, from his role as teacher, mentor and counselor. The group of individuals who have been Al Tucker's students, either literally or figuratively, has had a remarkably broad and deep impact on mathematical programming. The entire field has benefited from his stimulation and guidance. Therefore, it is especially appropriate that this prize, named in honor of Al Tucker should be for student research.

Andrew Goldberg was born in 1960 in Moscow and emigrated to the United States in 1979. He received a Bachelor of Science degree in Mathematics at MIT in 1982, a Master of Science degree in Computer Science at the University of California, Berkeley, in 1983 and a Doctor of Philosophy degree in Computer Science at MIT in 1987. He is now on the faculty of Stanford University in the Department of Computer Science.

The members of the Award Committee are Robert Bland, chair, Harold Kuhn, Alan Tucker and Laurence Wolsey.

–**Harold Kuhn**

## The 1988 Fulkerson Prizes

The Fulkerson Prize for outstanding papers in the area of discrete mathematics is sponsored jointly by the Mathematical Programming Society and the American Mathematical Society. Beginning in 1979, up to three awards are being presented at each (triennial) International Symposium of the Mathematical Programming Society. The prize was established to encourage mathematical excellence in the fields of research exemplified by the works of Delbert Ray Fulkerson.

The specifications for the Fulkerson Prize read:

***Papers to be eligible for the Fulkerson Prize should have been published in a recognized journal during the six calendar years preceding the year of the Congress. This extended period is in recognition of the fact that the value of fundamental work cannot always be immediately assessed. The prize will be given for single papers, not series of papers or books, and in the event of joint authorship the prize will be divided. The term "discrete mathematics" is intended to include graph theory, networks, mathematical programming, applied combinatorics and related subjects. While research work in these areas is usually not far removed from practical applications, the judging of papers will be based on their mathematical quality and significance.***

The Selection Committee for the Fulkerson Prize of 1988 consisted of Manfred Padberg (chairman), Martin Grötschel and Gian-Carlo Rota and recommended two awards. The recommendations (printed below) were accepted by the Mathematical Programming Society and the American Mathematical Society.

# Tokyo Symposium Report

### *First Award*

The Selection Committee recommended that one award be given to **Éva Tardos** for her paper, "A strongly polynominal minimum cost circulation algorithm," *Combinatorica* 5 (1985) 247-256.

Éva Tardos is a member of the Department of Computer Science, Eötvös Lorand University, Budapest, Hungary, currently visiting the Department of Mathematics, M.I.T., Cambridge, USA.

The minimum cost flow problem requires finding, in a directed graph with arc capacities and costs, a flow of given value and minimum cost. It is one of the central problems - with respect to theory and practice - in combinatorial optimization.

A first successful phase of research on this problem was in the late fifties and early sixties when Ford, Fulkerson, Minty and Yakovleva developed efficient algorithms for its solution.

Edmonds and Karp (1972) found an algorithm for the solution of the minimum cost flow problem that - provably - runs in polynomial time. A shortcoming of their algorithm is that the number of arithmetic operations performed is not bounded by any function of the combinatorial size (number of nodes and arcs) of the input and that it depends on the number of digits of the input numbers (costs). In their own words:

"A challenging open problem is to give a method for the minimum cost flow problem having a bound of computation which is a polynomial in the number of nodes, and is independent of both costs and capacities." [Edmonds & Karp, 1972]

Algorithms satisfying this requirement have later been termed "strongly polynomial". (For an exact definition of this term see, e.g., Johnson (1987) or Grötschel, Lovász, Schrijver (1988).)

The problem posed by Edmonds and Karp remained open for 13 years despite the fact that several eminent combinatorial optimizers had tried to solve it. Little progress was made in the direction of strong polynomiality until this problem was resolved by Éva Tardos in 1985.

The method of Tardos is based on original and beautifully simple ideas. Tardos' solution is iterative, but in contrast to the scaling techniques, her iterations reduce the number of constraints in the problem rather than increase the number of bits of accuracy in the solution. So the number of iterations is bounded by the number of constraints and independent of the data themselves. Éva Tardos' work shows a deep understanding of network flow techniques and throws new light on the notion of strong polynomiality. Apart from the evident theoretical significance of the notion of strong polynomiality, argued in detail, e.g., by David Johnson (1987) in his column, the impact of Tardos' breakthrough is indicated by the rapid subsequent developments (with Tardos herself leading the way). An improvement by Fujishige (1986) followed almost instantly. Tardos (1986) extended her method to solve any linear program with polynomially bounded integer coefficients in strongly polynomial time (independent of the real numbers that appear on the right hand side of the constraints and as coefficients of the objective function). Fujishige's work was further improved by Galil and Tardos (1986) and more recently by Orlin (1988) and the bound obtained became competitive, even in the classical sense, with the Edmonds-Karp bound.

ÉVA TARDOS RECEIVES A FULKERSON PRIZE

In another direction, Frank and Tardos (1987) gave a different and more general solution to the problem posed by Edmonds and Karp, using Lovász' algorithm for simultaneous diophantine approximation (cf. Lenstra, Lenstra, Lovász (1982)). This latter approach yields more general results as it hardly takes notice of the combinatorial structure of the constraints. Indeed, it works in combination with the ellipsoid method where polynomial-time optimization over certain combinatorially defined polytopes with exponentially many facets is achieved (see Grötschel, Lovász, Schrijver (1988)).

The insights gained from Tardos' fundamental results now highlight the problem of whether or not the general linear programming problem can be solved in strongly polynomial time. Tardos' paper represents one of the most significant advances in recent years in combinatorial optimization as well as in the theory of algorithms. It demonstrates that the new algorithmic paradigm used can successfully be employed to gain new insight into the structure of central problems of combinatorial optimization.

### *Second Award*

The Selection Committee recommended that one award be given to **Narendra Karmarkar** for his paper, "A new polynomial-time algorithm for linear programming," *Combinatorica* 4, (1984), 373-395.

Narendra Karmarkar is a Bell Labs Fellow at AT&T Bell Laboratories, Murray Hill, New Jersey, USA.

The linear programming problem is the problem of optimizing a linear objective function of several variables subject to linear constraints in the form of equations and inequalities. It is a problem of central importance in modern applied mathematics and provides a widely used model for the planning of economic activities in the public and private sectors. One of the reasons for

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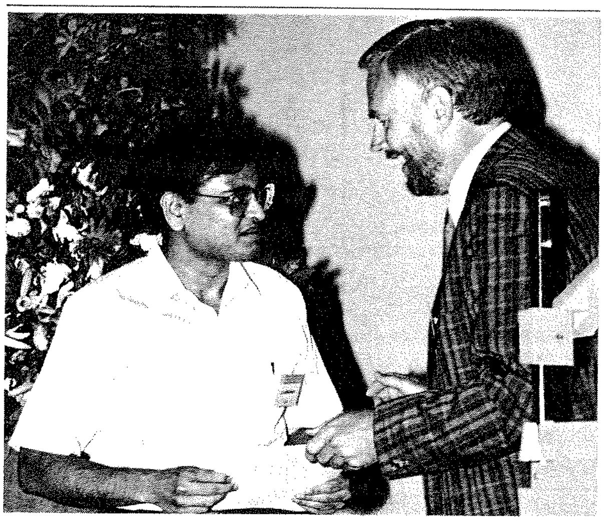
# Tokyo Symposium Report

## Prizes and Awards *continued*

the success of linear programming rests with the fact that it has become possible to solve the very large problem sizes that arise in todays' applications. The most frequently used method to solve linear programming problems to date is the simplex method.

The simplex method was invented around 1947 by George Dantzig. It starts by finding an extreme point of the polyhedral set defined by the linear constraints and proceeds by moving on an edge of the polyhedral set from one extreme point to a "better" adjacent one until a sufficient criterion for optimality is satisfied. It is thus an iterative method that finds an optimum by proceeding on the boundary of the polyhedral set. In his own words:



MARTIN GRÖTSHEL (RIGHT) AWARDS FULKERSON PRIZE TO NARENDRA KARMARKER.

"While the simplex method appears to be a natural one to try in the n-dimensional space of the variables, it might be expected, *a priori*, to be inefficient as there could be considerable wandering on the outside edges of the convex of solutions before an optimal extreme point is reached." [Dantzig, 1963, p.160]

Nevertheless, early computational studies beginning with Hoffman et al. (1953) established empirically the efficiency of the simplex method and its superiority to several alternative methods for the resolution of linear programming problems. The basic question of the worst-case behavior of the simplex method was settled in the negative by Klee & Minty (1972). It took ten more years before the fundamental question of polynomial solvability of linear programming problems was answered in the positive by the ellipsoid method of Khachiyan (1979). (Fulkerson prizes for this work were awarded in 1982.)

Narendra Karmarkar's work presents a new polynomial-time algorithm for linear programming that requires $O(n^{3.5}L)$ arithmetic operations on $O(L)$ bit words where $n$ is the number of variables and $L$ is the number of bits in the input. To achieve this result the general linear programming problem is first brought into a standard form that permits a feasible starting point in the center of a simplex. The iterative step consists of optimizing a linear function subject to a homogeneous system of equations over a sphere inscribed into the simplex and the subsequent application of a projective transformation that maps the new iterate back into the center of the simplex. The linear objective function that is optimized at each step changes from iteration to iteration. The sequence of points generated this way is shown to converge to an optimal solution in polynomial time using a surrogate objective function that ensures the necessary monotonicity and decrease from step to step.

Different from the simplex method and the ellipsoid method Narendra Karmarkar's algorithm is an interior point method that realizes the intuitively most appealing idea of "shooting" through the polyhedron to an optimal point. It is based on a genuinely new idea and has revived interest in the search for faster and ever more efficient ways of solving large-scale linear programming problems. Within a short span of four years, Karmarkar's new method has already generated numerous subsequent developments, given a fresh impulse to the field of mathematical programming and increased the hope of extending linear and nonlinear programming problem-solving capabilities to problems of sizes bigger than those solved today.

An entire issue - edited by Nimrod Megiddo (1986) - of the journal *Algorithmica* is devoted to related nonlinear programming approaches to linear programming. Papers by Iri and Imai (1986), de Ghellinck and Vial (1986) and others explore Newton-type and related descent methods for linear programming. Karmarkar's work stimulated renewed interest in the "barrier methods" of nonlinear programming, see e.g. Gill, Murray, Saunders, Tomlin and Wright (1986). Connections to areas of classical mathematics such as partial differential equations, differential geometry and convexity are investigated in several papers by Bayer and Lagrias (1986). Affine variants of Karmarkar's algorithm are discovered and rediscovered, see Dikin (1967) and Barnes (1986). Huard's method of analytic centers (1967) is re-examined in a new light, see Sonnevend (1985) and Mehrotra and Sun (1988).

In summary, Narendra Karmarkar's work represents one of the most significant advances in recent years in mathematical programming as well as in the theory of algorithms and has already left a major imprint on the field of linear and nonlinear computation.

### *References*

[1] E. Barnes (1986), A Variation on Karmarkar's Algorithm for Solving Linear Programming Problems. *Mathematical Programming*, 36:174-182.

[2] D.A. Bayer and J.C. Lagarias (1986), The Nonlinear Geometry of Linear Programming. *Preprints* AT&T Laboratories, Murray Hill, NJ.

[3] G.B. Dantzig (1963), *Linear Programming and Extensions.* Princeton University Press, Princeton, NJ.

[4] G. de Ghellinck and J.-P. Vial (1986), A Polynomial Newton Method for Linear Programming. *Algorithmica*, 1:425-453.

[5] I.I. Dikin (1967), Iterative Solution of Problems of Linear and Quadratic Progamming. *Soviet Mathematics Doklady*, 8:674-675.

[6] J. Edmonds and R.M. Karp (1972), Theoretical Improvements in Algorithmic Efficiency for Network Flow Problems. *Journal of Association for Computing Machinery*, 19:248-264.

[7] A. Frank and É. Tardos (1987), An Application of Simultaneous Approximation in Combinatorial Optimization. *Combinatorica*, 7:49-65.

[8] S. Fujishige (1986), A Capacity-Rounding Algorithm for the Minimum-Cost Circulation Problem: A Dual Framework of the Tardos Algorithm. *Mathematical Programming*, 35:298-308.

[9] Z. Galil and É. Tardos (1986), An $O(n^2(m + n \log n) \log n)$ Min-cost Flow Algorithm. *Proc. 27th IEEE FOCS Symp.*, Toronto, 1-9.

[10] P.E. Gill, W. Murray, M.A. Saunders, J.A. Tomlin and M.H. Wright (1986), On Projected Newton Barrier Methods for Linear Programming and An Equivalence to Karmarkar's Projective Method. *Mathematical Programming*, 36:183-209.

[11] M. Grötschel, L. Lovász and A. Schrijver (1988), *Geometric Algorithms and Combinatorial Optimization*. Springer Verlag, Heidelberg.

[12] A.J. Hoffman, M. Mannos, D. Sokolowsky and N. Wiegman (1953), Computational Experience in Solving Linear Programs. *J. Soc. Indust. Appl. Math.*, 1:17-33.

[13] P. Huard (1967), Resolution of Mathematical Programming with Nonlinear Constraints by the Method of Centers. In J. Abadie, Editor, *Nonlinear Programming*, North-Holland, Amsterdam.

[14] M. Iri and H. Imai (1986), A Multiplicative Barrier Function Method for Linear Programming. *Algorithmica*, 1:455-482.

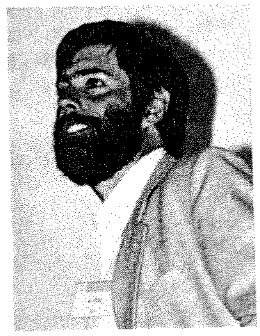
[15] D.S. Johnson (1987), The *NP*-Completeness Column. *Journal of Algorithms*, 8:285-303.

[16] L.G. Khachiyan (1979), A Polynomial Algorithm in Linear Programming. *Soviet Mathematics Doklady*, 20:191-194.

[17] V. Klee and G. Minty (1972), How Good is the Simplex Method? In O. Shisha, Editor, *Inequalities-III*, Academic Press, New York and London, 159-175.

RIGHT: DANTZIG PRIZE WINNER MICHAEL TODD DELIVERS PLENARY LECTURE.

**BELOW: LAURENCE WOLSEY ACCEPTS THE ORCHARD-HAYES PRIZE FROM JOHN TOMLIN ON BEHALF OF HIMSELF AND TONY VAN ROY FOR THIER JOINT WORK IN INTEGER PROGRAMMING.**



[18] A.K. Lenstra, H.W. Lenstra, Jr. and L. Lovász (1982), Factoring Polynomials with Rational Coefficients. *Mathematische Annalen*, 261:515-534.

[19] N. Megiddo (1986), Introduction: New Approaches to Linear Programming. *Algorithmica*, 1:387-394.

[20] S. Mehrotra and Jie Sun (1988), A Method of Analytic Centers for Quadratically Constrained Convex Quadratic Programs. *Preprint*, Northwestern University, Evanston, IL.

[21] J.B. Orlin (1988), A Faster Strongly Polynomial Minimum Cost Flow Algorithm. In: Proc, *20th ACM Symp. on Theory of Computing*, 377-387.

[22] G. Sonnevend (1985), An "Analytical Center" for Polyhedrons and new Classes of Global Algorithms for Linear (Smooth, Convex) Programming. In A. Prekopa, J. Szelezsan and B. Strazicky, editors, *Systems Modelling and Optimization.* Lecture Notes in Control and Information Sciences 84, Springer, Berlin, 866-875.

[23] É. Tardos (1986), A Strongly Polynomial Algorithm to Solve Combinatorial Linear Programs. *Operations Research*, 34:250-256.

# Mike Todd Receives 1988 Dantzig Prize

The 1988 George B. Dantzig Prize has been awarded to **Michael J. Todd**, Leon C. Welch Professor, in the School of Operations Research and Industrial Engineering at Cornell University. The character for this award specifes that, "The prize is awarded for original work, which by its breadth and scope, constitutes an outstanding contribution to the field of mathematical programming." It is precisely the breadth and scope of Professor Todd's many important contributions in mathematical programming which form the basis for this award.

The extraordinary success of linear programming, ranging from broad practical applicability of the linear model to its supporting combinatorial and computational methodology, is the cornerstone of the field of mathematical programming. Indeed, it is primarily Dantzig's seminal accomplishments in this area which this prize seeks to commemorate. Today, some four decades after the introduction of the simplex method, linear programming remains a very active and fertile area for research, as evidenced by recent work on (i) oriented matroids as an abstract combinatorial model for linear programming and the simplex method, (ii) average-case analysis of the simplex algorithm as an approach to explain its observed computational efficiency and (iii) polynomial-time ellipsoidal and interior-point algorithms for linear programming.

Professor Todd is perhaps the only researcher to have made fundamental advances on each of these three topics of present-day research. His work, however, is not limited to the topic of linear programming. He has also made important contributions to the study of large structured mathematical programming problems and to the development and analysis of algorithms for solving systems of nonlinear equations, particularly with application of economic equilibrium problems.

The award, which is joint with SIAM, was presented at the SIAM annual meeting in July and announced at the opening session of the MPS Tokyo meeting.

**–Les Trotter**

# Conference Notes

## 14th IFIP Conference on System Modeling and Optimization

***July 3-7, 1989; Leipzig, GDR***

The conference will be held in the Congress Centre of the Karl-Marx-University in the city centre of Leipzig. The aim of the conference is to discuss recent advances in the mathematical representation of engineering, socio-technical and socio-economical systems as well as the optimization of their performances. The language of the conference will be English.

Abstracts and software descriptions should be submitted by December 15, 1989. Contact: **Dr. K. Tammer, Leipzig University of Technology, Department of Mathematics and Informatics, PF 66, Leipzig, 7070, GDR.**

## SIAM Conference on Optimization

***April 3-5, 1989; Boston, MA***

The third SIAM Conference on Optimization will be held April 3-5, 1989, at 57 Park Plaza Hotel, Boston, MA. Themes of the conference include Interior Point Methods for Linear Programming, Network Optimization, Constrained Optimization and Large-Scale Optimization. The Organizing Committee is Donald Goldfarb (Columbia) and Michael Todd (Cornell), Co-chairs, with David Gay (AT&T Bell Labs) and Jorge More (Argonne).

Preceding the conference there will be a short course on Recent Developments in Linear and Nonlinear Programming organized by Richard Stone and Margaret Wright of AT&T Bell Laboratories.

Deadline for contributed abstracts and poster sessions is November 4, 1988.

Contact: **SIAM Conference Coordinator, 117 South 17th Street, 14th Floor**
**Philadelphia, PA 19103-5052**
**Telephone (215) 564-2929**
**Email:** siam@wharton.upenn.edu; **Fax:** 215-564-4174.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*D.A. Stanford, B. Pagurek and C.M. Woodside*
The serial correlation coefficients for waiting times in the stationary $GI/M/m$ queue

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Transient solution for a finite capacity $M/G^{a,b}/1$ queueing system with vacations to the server

*V. Anantharam*
Probabilistic proof of the interchangeability of ./M/1 queues in series

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A bibliography of books and survey papers on queueing systems: Theory and applications

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# Technical Reports & Working Papers

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H. Belouadah, M.E. Posner and C.N. Potts, *"A Branch and Bound Algorithm for Scheduling Jobs with Release Dates on a Single Machine to Minimize Total Weighted Complete Time,"* OR14.
H.P. Williams, *"Orthogonality in Linear Congruence Duality,"* OR9.
V.J.D. Baston, M.K. Rahmouni and H.P. Williams, *"The Practical Conversion of Linear Programmes to Network Flow Models,"* OR10.
K.I.M. McKinnon and H.P. Williams, *"Constructing Integer Programming Models by the Predicate Calculus,"* OR11. Y. Ouinten and A.K. Shahani, *"Modelling for an Early Detection of Breast Cancer,"* OR13.
Y. Maghsoodi, *"Design and Computation of Near-Optimal Stable Observers for Bilinear Systems,"* OR15.
V.J.D. Baston and F.A. Bostock: *"A Continuous Game of Ambush," "Discrete Hamstrung Squad Car Games," "Deception Games," "An Evasion Game with Barriers," "A Simple Cover-up Game," "A One Dimensional Helicopter-Submarine Game," "The Number Hides Game,"* (with T. Ferguson).

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M. Leclerc, *"Constrained Spanning Trees and the Travelling Salesman Problem,"* WP 88.55.
M. Leclerc, *"A Class of Latices,"* WP 88.54.
M. Leclerc, *"Fast Polynominal Arithmetic and Exact Matching,"* WP 88.53.
M. Leclerc, *"A Linear Algorithm for Breaking Periodic Vernam Ciphers,"* WP 88.52.
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M. Alfter, W. Kern and A. Wanka, *"On Adjoints and Dual Matroids,"* WP 88.49.
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M. Leclerc, C.H.C. Little and F. Rendl, *"Constrained Matching Problems and Pfaffian Graphs,"* WP 87.41.
M. Leclerc and F. Rendl, *"A Multiply Constrained Matroid Optimization Problem,"* WP 87.40.

# *Election Results of the 1988 Mathematical Programming Society*

Chairman: George L. Nemhauser (USA);
Treasurer: Leslie E. Trotter, Jr. (USA);
Council Members-at-Large: Egon Balas (USA), William Cunningham (Canada), Claude Lemarechal (France), Alexander Schrijver (Netherlands).
By the terms of the constitution of the Society this determines the following future periods of service of elected officers:
Chairman: Michel L. Balinski (through 8/1989), George L. Nemhauser (9/1989- 8/1992);
Treasurer: Albert C. Williams (through 8/1989), Leslie L. Trotter, Jr. (9/1989-8/1992);
Council: Egon Balas (9/1988-8/1991), Michel L. Balinski (9/1988-8/1989 Chairman and 9/1989-8/1991 Vice-Chairman), William H. Cunningham (9/1988-8/1991), Claude Lemarechal (9/1988-8/1991), George L. Nemhauser (9/1988- 8/1989 Vice-Chairman and 9/1989-8/1992 Chairman, 9/1992-8/1994 Vice-Chairman), Leslie L. Trotter, Jr. (9/1989-8/1992), Alexander Schrijver (9/1988-8/1991) and Albert C. Williams (9/1988-8/1989).

# JOURNALS

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H. Kawasaki, *"The Upper and Lower-Second Order Directional Derivatives of a Sup-Type Function."*
R.E. Moore and H. Ratchek, *"Inclusion Functions and Global Optimization II."*
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D.M. Ryan and M.R. Osborne, *"On the Solution of Highly Degenerate Linear Programs."*
E. Balas and S.M. Ng, *"On the Set Covering Polytope: I. All the facets with Coefficients in {0,1,2}."*
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A. Ech-Cherif, J.G. Ecker and M. Kupferschmid, *"A Numerical Investigation of Rank-Two Ellipsoid Algorithms for Nonlinear Programming."*
R.J. Caron and J.F. McDonald, *"A New Approach to the Analysis of Random Methods for Detecting Necessary Linear Inequality Constraints."*
B. Ram and M.H. Karwan, *"A Result in Surrogate Duality for Certain Integer Programming Problems."*

## Series A
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R. Mifflin and J.-J. Strodiot, *"A Bracketing Technique to Ensure Desirable Convergence in Univariate Minimization."*
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C.C. Gonzaga, *"Conical Projection Algorithms for Linear Programming."*
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# BOOK REVIEWS

## *Parallel Computers and Computations*

Edited by J. van Leeuven and J. K. Lenstra
CWI Syllabus 9
Amsterdam, Netherlands, 1986
ISBN 90-6196-297-8

While hardware is becoming cheaper, one approach to obtain faster computing machines is to provide several instances of functional units in a system that can operate concurrently. But as there are a number of possible bottlenecks in a system (memory, communication paths, arithmetic units, etc.) - and to judge which components are strongly depends on the type of task to be performed - a corresponding large number of architectural designs with varying degrees of parallelism and applicability has emerged on the market.

This volume contains eight papers covering various aspects of parallel computers and computation which were presented during the fall of 1983 at the University of Utrecht.

The first paper introduces several models of parallel machines, techniques of a parallelization and hints at the benefits that can or cannot be expected from parallel algorithms even if designed close to the hardware and communication schemes involved. A comparison of two supercomputers, namely the Cray-1 and the Cyber 205, which can, roughly spoken, both be categorized as vector processing machines, with respect to the impact of the "minor" architectural differences on the optimal design of programs for some basic problems in linear algebra, is discussed in the second paper. The third paper presents some techniques to introduce parallelism into algorithms for linear algebra and for the solution of partial differential equations.

In order to be able to exploit the parallelism of a hardware scenario, a suitable operating system has to be provided. The fourth paper presents some internal details of the CDC 205 operating system nucleus, while the fifth gives an overview of the Amoeba distributed and capability based operating system.

Trace theory as a formal specification scheme for the design and synthesis of parallel programs is presented in the sixth paper, and the seventh discusses various approaches to introduce parallelism into complexity theory and the consequences on the results obtainable by using different machine models. Finally, a tutorial introduction to the literature on parallel computers and algorithms relevant to combinatorial optimization is given.

As an introduction to the various aspects of parallelization of computing machinery and algorithms, this book can be recommended to everyone who is interested in a closer look at this important topic.

– **O. Holland**

## *Theory of Matroids*

Edited by Neil White
Cambridge, 1986
ISBN 0-521-30937-9

This book is the first of a three-volume series which is to present essential results about matroids. Since matroid theory accelerated rapidly during the last 50 years, it is of course impossible to treat all aspects in only one book. The main points of the first volume are matroid cryptomorphisms and constructions of matroids. Most of the theorems are proved in detail; however, the more difficult results and most of the new results derived during the last 10 years are stated without proof but with references given to the original works.

The book consists of 10 chapters contributed by several authors. The first chapter by Henry Crapo gives some motivations for matroid theory. In particular, it is explained that matroids comprise many configurations met in pure and applied mathematics. Here and throughout the whole book, the examples of vectorial, projective and affine geometries, graphical matroids and transversal matroids are examined in great detail.

In the second chapter by Giorgio Nicoletti and Neil White some of the major axiom systems for matroids (in terms of bases, independent sets, circuits etc.) are proved to be equivalent. In an appendix to the book some further axiom

CONTINUES

# BOOK REVIEWS

systems for matroids are given and the relations between all of them are described in detail.

In the third chapter, Ulrich Faigle presents the lattice-theoretic approach to matroids. One of the main results is the well-known theorem that the lattices of flats of matroids are exactly the geometric lattices up to isomorphism.

The fourth chapter by Joseph P. S. Kung deals with exchange properties of bases of matroids. In particular, many well-known theorems of linear algebra concerning bases of vector spaces are generalized. Furthermore, it is remarked that several exchange theorems, which can be proved for vectorial matroids by using identities concerning determinants, up to now have only been generalized in special cases.

In the fifth chapter Henry Crapo explains the duality concept in matroid theory. Several descriptions of the dual of a matroid are given based on the different axiom systems for matroids. One of the main theorems states that a matroid is representable over some field F if and only if its dual is representable over F too.

James Oxley examines graphical matroids in the sixth chapter. Every graph is related to some polygon matroid in a canonical way. A very important result states that a graph is planar if and only if the dual of its polygon matroid is itself a polygon matroid. This theorem is reduced to Kuratowski's well-known theorem which states that a graph is nonplanar if and only if it contains a subgraph homeomorphic from the complete graph K5 or the complete bipartite graph K3,3.

The seventh chapter by Thomas Brylawski is the longest in the book and deals with constructions of matroids from given matroids. The main themes are restrictions, contractions, truncations and extensions of matroids as well as direct sums and several generalizations. For all these constructions many equivalent definitions are given in terms of the different descriptions of matroids. Furthermore, this chapter includes the concept of matroid bracing, unpublished before, which yields certain canonical extensions of matroids.

In the eighth and ninth chapters Joseph P. S. Kung and Joseph P. S. Kung together with Hien Q. Nguyen, respectively, discuss two suggestions of morphisms between matroids, namely strong maps in the eighth and weak maps in the ninth chapter. Both types may be interpreted as abstractions of linear maps between vector spaces. However, weak maps are much more general. The main subject in both chapters is the proof of factorization theorems which allow representing strong maps as well as weak maps as compositions of particularly simple maps. The concept of a weak cut is described, which was discovered in 1979 by Nguyen and, independently, in 1980 by Kung and serves to determine whether or not the identity map between two matroids, defined on the same set, is a weak map. A result which characterizes weak cuts completely is included together with a new proof based on a suggestion by J. Mason.

The 10th chapter by Hien Q. Nguyen deals with relations between semimodular functions and matroids. An integer-valued function f defined on some finite lattice with $f(0) = 0$, which is non-decreasing and semimodular, is extended to some function $\bar{f}$ defined on a Boolean algebra such that $\bar{f}$ may be interpreted as a rank function of some matroid.

Apart from the first, each chapter contains a long list of references. However, a single index of all cited works would have been very useful.

While the book, *Matroid Theory*, by D. J. A. Welsh (1976) is more elementary, the new book by Neil White considers more difficult problems. So, in my opinion, the book by Welsh is more appropriate for a first course on matroids, while this book, *Theory of Matroids*, by Neil White is a very good reference for those familiar with the essential elements of matroid theory.

**– W. Wentzel**

## *Functional Analysis and Control Theory*

by Stefan Rolewicz
Reidel, Dordrecht, 1987
ISBN 90-277-2186-6

This is a very nice and clearly written book on the mathematical theory of linear control systems in the terminology of functional analysis. It should be thought of as an introduction to mathematical control theory for applied mathe-

# BOOK REVIEWS

maticians and systems engineers and is written at a high mathematical level. It contains many instructive examples and the theoretical mathematical concepts are well motivated.

The book starts with some fundamental facts about topology and measure theory. Then an excellent presentation of the needed apparatus of functional analysis follows. The most essential part of this book is chapter 5 where the theory of general linear systems is developed. Although this chapter seems to be rather abstract, it permits the answering of some fundamental questions, for instance, the meaning of the Pontryagin-maximum principle for linear systems. Moreover, it contains important theorems about the existence of universal time for time depending linear systems. Optimal observability is defined in a general way, and the duality between optimal observability and optimal controllability is presented. These results are then applied to finite dimensional systems described by linear ordinary differential equations and to systems with distributed parameters governed by the diffusion equation. In this connection the author presents all the fundamental facts about differential equations in Banach spaces. In particular, he treats in detail the results on control of heating and observability of temperature distributions in a slab under various boundary conditions.

This book contains several extensions to the Polish and German editions. An appendix containing necessary and sufficient conditions for weak duality, obtained by the Dolecki-Kurczyusz method of multifunctions, is included.

**– D. Pallaschke**

## *Search Problems*

by R. Ahlswede and I. Wegener
Wiley, Chichester, 1987
ISBN 0-471-90825-8

This monograph brings together a collection of results pertaining to problems that can be labeled as *search problems*. A very wide spectrum is covered ranging from optimal binary search trees to constructing optimal allocations through searching for the maximum of a unimodal function and stochastic approximation. The book is divided into four parts and 13 chapters.

The material is well organized and well presented. It is not, however, addressed to the general audience. As the authors state in the preface, the book is addressed to the expert. Indeed, a reader familiar with particular topics will find the chapters devoted to these topics easy to follow. Chapters treating unfamiliar topics, on the other hand, will require substantial effort. In some instances the choice of terminology is unfortunate (a computer scientist may wonder why *binary search* refers to something other than the famous algorithm). In other instances the choice of topic is questionable (a chapter is devoted to *sorting* in a book on *searching*, yet the obvious connections are not drawn). The book does not cover the following problems: searching graphs (e.g. depth-first search, breadth-first search, best-first search, branch-and-bound search, etc.) searching game trees (e.g. minimax search, alpha-beta search, etc.), searching combinatorial spaces (e.g. heuristic search), geometric search (e.g. point location problems), and database queries (e.g. multidimensional querying).

Despite the above criticisms, the book is a valuable contribution to discrete mathematics and the design and analysis of algorithms.

**– S. G. Akl**

## *Applied Probability and Queues*

by S. Asmussen
Wiley, Chichester, 1987
ISBN 0-471-91173-9

In the Preface the author writes, "This book treats the mathematics of queueing theory and some related areas, as well as basic mathematical tools relevant for the study of such models.... Particular attention has been given to modern probabilistic points of view, as alternatives to traditional analytic methods. Within this framework the choice of the topics is, however, rather traditional."

CONTINUES

# BOOK REVIEWS

The book is subdivided into three parts. In Part A, bearing the title, Simple Markovian Models, the Markov chains and the Markov jump processes are described, and the reader is introduced to queueing theory where elements of queueing networks are also included.

Part B has the title, Basic Mathematical Tools. Here renewal theory, regenerative processes and random walks are discussed.

Part C is devoted to Special Models and Methods. Here one finds the exposition of the theory of various special single-server and many-server queues, multi-dimensional Markov processes, and conjugate processes and some special models playing an important role in applications such as insurance, dam and storage models. An appendix about selected background material (point processes, stochastic ordering, Wald's identity, etc.) closes the book.

The reviewer thinks that it is primarily a postgraduate level book. Looking at it as such, the mathematical elegance is what we primarily observe and praise here. If, however, one wants to use it as a textbook for a graduate course, then a more elementary knowledge of the theory of stochastic processes has to be included among the prerequisites.

**– Andras Prekopa**

## *The Simplex Method*
## *A Probabilistic Analysis*

by Karl-Heinz Borgwardt
Springer, Berlin, 1987
ISBN 3-540-17096-0

For an edge-following LP algorithm like the simplex algorithm the maximum number S(m,n) of basis exchanges or pivot steps required to solve a problem in n variables and m inequality constraints is a reasonable and much studied measure for the worst-case behavior of the algorithm. Edge-following LP algorithms differ mainly by the selected pivot rule, and clearly S(m,n) depends on that choice.

Encouraged by empirical results observed in practical applications in the 1950s and '60s, there was some belief that there might be a pivot rule for which S(m,n) is bounded by a (linear) polynomial in m and n. However, in the early '70s Klee and Minty proved that for the Dantzig pivot rule, there are positive constants $\alpha_n$ and $\beta_n$, depending on n only, such that

$$\alpha_n m^{[n/2]} < S(m,n) < \beta_n m^{[n/2]} \text{ for all } m > n.$$

Hence, for a very common pivot rule this optimistic assumption about the behavior of the functional S(m,n) was shown to be incorrect. Later, such negative results were proved for almost all common pivot rules. It is an open problem whether a pivot rule with polynomial S(m,n) exists or not.

The proved bad worst-case behavior of most known pivot rules contrasts the observed performance in practice, and so it is natural to ask for the average-case behavior of S(m,n). In a series of papers, Borgwardt was the first to provide a quite satisfactory analysis of this behavior for a special pivot rule. Briefly, he proved a polynomial bound for the expectation value of S(m,n) under some reasonable stochastic assumptions about the input data.

The book under review contains a very detailed description of those results, their proofs and some extensions.

The problems dealt with are of the following kind: Maximize $v^T x$ subject to $a_1^T x \leq 1, \ldots, a_m^T x \leq 1$ where v, x, $a_1, \ldots, a_m \varepsilon R^n$, and $m \geq n$.

For the stochastic considerations it is assumed that $a_1, \ldots, a_m$, v are distributed (on $R^n \setminus \{0\}$ independently, identically, and symmetrically under rotations. The pivot rule considered by the author is the Gass-Saaty rule of parametric linear programming. The main result states that the complete problem (including Phase I) requires not more than $cm^{1/n-1}(n+1)^4$ pivot steps on the average, where c is a constant. It should be noted that the selected pivot rule in this model is by no means *exotic*. The rule is, in fact, the standard method for producing the efficient solutions for an LP with two objectives.

The Gass-Saaty pivot rule has the advantage that pivots can be described geometrically by means of a line crossing a system of cones spanned by the vectors $a_1, \ldots, a_m$. The author calls this cone approach a *dual* version. It should be called a polar approach as it deals with the polar of the feasible

# BOOK REVIEWS

polyhedron. The algorithm is not the dual one for the primal problem in the sense of LP theory. The expected number of pivots can be expressed as an integral over spherical measures of such cones. Actually, the evaluation of this integral is very involved and it is the essential part of the stochastic analysis. Two chapters of the book and the appendix are devoted to the evaluation of such integrals. The interested reader is provided with all the details of the computation. This will be appreciated by those who try to become familiar with the methods of this active area of research.

Several ramifications of the problem are also presented, including problems with nonnegativity constraints, the restriction to Phase II, asymptotic results and special distributions. The reader who is not interested in all the technical details will find the main results and ideas in the first chapter. It also includes an interesting survey of the results obtained by other researchers. Alternative stochastic models, especially the sign-invariance model, are discussed.

The book is written very clearly. The reader is well guided through the difficult technical parts. For this purpose the numerous illustrations of the geometry involved prove very helpful. I recommend this book to anyone interested in questions related to the performance of LP algorithms. In addition, because of its geometric approach, it will also be of considerable interest to those working in stochastic or convex geometry.

**– P. Kleinschmidt**

## Application for Membership

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# Gallimaufry

The MPS Symposium in Tokyo had one extremely sad note. **Robert G. Jeroslow** (Georgia Tech) died of an apparent heart attack while attending the meeting. Symposium attendees expressed their written condolences in a volume which was assembled and sent to his son Avi.

An international conference on parallel computing was held in Verona, Italy, September 28-30. Proceedings will be edited by **D. J. Evans** (Loughborough Univ., U. K.) and **C. Nordai Sutti** (Univ. di Verona)...**J. K. Lenstra** has agreed to serve as MPS liaison with the International Statistical Institute which handles the Society business affairs. Members may contact him if they have problems with ISI. Address is Centre for Mathematics and Computer Science, P. O. Box 4079, 1009 AB Amsterdam, The Netherlands; telephone: +31-20-592-4087; email: jkl@cwi.nl...The MPS Executive Committee has announced solicitations for a site for the 1994 Symposium...A Call for Papers dealing with topics on Local Optimization has been announced for a special issue of Discrete Applied Mathematics by Editor **Donna Crystal Llewellyn**, ISyE, Georgia Tech, Atlanta GA 30332-0205; telephone: 404-894-2340; email: dllewell@gtri01.bitnet. The Eleventh Symposium on Mathematical Programming with Data Perturbations will be held 25-26 May, 1989 at the George Washington University. Contact **Anthony Fiacco** (202) 994-7511.

Deadline for the next OPTIMA is February 1, 1989.

***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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