JANUARY
1 9 8 5
NUMBER 14

OPTIMA

MATHEMATICAL PROGRAMMING SOCIETY NEWSLETTER

12th International Symposium on Mathematical Programming at MIT

August 5-9, 1985

Deadlines:

Contributed Paper Titles - April 1, 1985
Abstracts – May 15, 1985

Contact:

Symposium Secretary
Operations Research Center
E40-164
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139 USA
(617) 253-3601

The Programming of (Some) Intelligence: Opportunities at the OR/AI Interface

Robert G. Jeroslow, Georgia Institute of Technology

IN recent years "artificial intelligence" (AI) and, more specifically, the "expert system" (ES) approach within the AI area have captured the popular imagination. Here in this article I shall be very topical and trendy. First, however, I want to be clear about the intellectual issues involved.

For about three years now, I have been studying some of the mathematical aspects of the process of taking a "real-world" situation and representing it (when possible) by a mixed-integer (linear or convex) program in binary integers. Much of this work began as joint with James K. Lowe.

The mathematical form in which my own inquiries have recently converged lies in elucidating the relationship between formulation settings. I am interested in studying this 'modelling process' because of the possibilities for extending the use of OR models in a decision support context.

Let us conceptualize the matter this way. There is some domain Ω, a subset of the Cartesian product of X and D, where X is the "spatial component" (i.e. is a subset of some Euclidean space) and D is the "logical component" (i.e., the rest). Here X and D may themselves also be Cartesian products. On Ω there is a set of "predicates" (also called "relations") $P_1, P_2 \ldots$ A predicate P_j is simply a subset of Ω.

Each of the predicates P_j has a "negation" $\neg P_j$, which is simply its set-theoretic complement in $\Omega: \neg P_j = \Omega \setminus P_j$.

Here is what we seek: we wish to "imbed" the entire structure Ω and its predicates $P_1, P_2, \ldots$ into a space—the non-spatial D along with the spatial part X – in a way that "preserves" the spatial part X in terms of optimization. After all, mathematical programming algorithms generally operate in Euclidean space, so we have to first get the structure there!

More specifically, we wish to find subsets Imb (Ω) and Imb (P_j), Imb$(\neg P_j)$ (all j) of some Euclidean space, with a number of properties: 1) The Imb(Ω) and Imb(P_j), Imb$(\neg P_j)$ are representable using constraints of a mixed-integer type in binary variables and have a common recession cone; 2) Imb $(P_j) \cup$ Imb$(\neg P_j)$ = Imb(Ω) and Imb $(P_j) \cap$ Imb $(\neg P_j) = \phi$; and 3) for any logical form £ involving only the propositional connectives of 'or' (abbreviated as 'V'), 'and' ('Λ'), 'implies' ('→') and 'not' ('¬') and any linear criterion vector 'c', we have

$$(*) \quad \inf\{cx \mid (x,d) \in £\} = \{\min cx \mid (x,y) \in \text{Imb}(£)\}$$

WE now explain (3) and (*) in some detail. It allows conditions like £=(P_1 but not (P_2 and not P_5)) and (not P_3 or P_5). So here Imb(£)= Imb$(P_1) \cap$ (Imb$(\neg P_2) \cup$ Imb$(P_5)) \cap$ (Imb$(\neg P_3) \cup$ Imb (P_5)).

Under rather broad conditions imbeddings exist, so optimization over Ω can be done entirely by spatial techniques from mathematical programming e.g., branch-and-bound (that is the significance of (*)).

Curiously enough, even for familiar logical implications frequently done by MIP in the past, there turn out to be new spatial imbeddings which appear to be more advantageous.

From a practical perspective, one is more concerned with the linear relaxation of the imbedding Imb(£). This is what guides the branch-and-bound search tree. A good deal can be said about the possible imbedding and the strength of the associated relaxation. Generally, there are "a lot" of them and one wants those with "undominated" relaxations, relative to the size of the (linear or convex) system. A study of these relaxations requires further and systematic develop-

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Society Seeks Host for 13th Symposium

The Mathematical Programming Society is beginning its planning for the Thirteenth International Symposium on Mathematical Programming, which it proposes be held about the last week in August, 1988, somewhere in the world other than North America. It wishes hereby to invite all parties who might act as hosts to this event to make their interest known to the Society's Symposium Advisory Committee.

The Society's practice with regard to the Symposia has been to give the host committee considerable autonomy in the whole affair. The Society has some guidelines for conducting the Symposium, traditions it wishes to maintain, and a large body of experience on which the host can draw. (The committee

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ment of that part of the "disjunctive methods" that Egon Balas and I have worked on.

Many "expert systems" need only a small fragment of the modelling potentialities sketched above.

When the "expert" in an ill-structured area describes his/her heuristic rules by means of "productions," they are cast in the form:

(I) If A_i with MB x_i ($i = 1,..,t$) then B with MB y.

In (I), the A_i and B describe conditions such as: "The patient has pneumonia" The measures of belief (MBs) x_i and y are real numbers (usually in $[0,1]$) and y is a function of the x_i: $y = f(x_1,..., x_t)$.

Certain initial values of the MBs are given, in addition to the rules (I). These may come from diagnostic tests run on a specific patient. In contrast, the production rules (I) represent general principles.

Many different functions f have been suggested; one is the minimum: $y = f(x_1,...,x_t) = \min x_i$. Then the belief in B is the maximum of all such y, over all rules (I) which conclude B, together with the original MB of B; and the chaining process of taking minima (in(I)) and then maxima, is repeated. When the confidence in some conclusion like B (which is a function $j(y,y')$ of the MB y of B and the MB y′ of ¬B) is "suitably high," the truth of B may be "concluded."

THIS summarizes my own treatment of MBs and "confidence factors" (CFs) calculated as $j(y,y')$. For me the MB y of B is a measure of the strength of evidence in favor of B, ignoring contrary evidence; while the MB y′ of ¬B summarizes only the evidence against B. In this treatment MB is like a "myopic barrister," the two barristers make cases y and y′ which go to a "jury" $j(y,y')$.

Incidentally, even for zero-one valued MBs, the above treatment and existing treatments will not recover boolean (propositional) logic. Note that the two rules A→B and ¬A→B assure that B is true (as A∨¬A is true). However, starting with zero MBs for A and ¬A, one will not get an MB of "one" for B in existing treatments.

There are variations in how the rules like (I) are used. In other treatments the computation of the MBs and confidence are done differently.

For the minimum function $y = \min\{x_1,...,x_t\}$, one can obtain a representation of its epigraph using linear mixed-integer constraints in binary variables. Using this representation, the end result of a complete chaining process can be obtained from solving a mixed-integer program (MIP). Other monotone, representable functions are also treated by MIP.

The technical advantage of the "myopic barrister" approach lies in its ability to obtain, from one MIP, the limits of a very long finite (or even infinite) process of repeated chaining provided these limits exist and are not less than the initial MB values.

At the present time, the use of MBs lacks a consistent and sound axiomatic foundation for their use. Such a foundation may well be feasible and was done earlier for the use of probability in models.

Of course, when the CFs are not present, an "expert system" becomes a conventional satisfiability problem. From empirical results on many randomly-generated problems (with t less than seven), it emerged in experiments run by Jim Lowe that the usual integer programming techniques were very effective.

I have gone into detail regarding some of my own current research in order to indicate how issues in the "OR/AI interface" can often be made exact and subject to a mathematical development. I am developing "machinery" to explore some topics which appeal to me.

AI is a very broad area which yields to many different mathematical approaches and techniques. There will be multiple ways of using OR in AI and vice versa. Since the terrain of the "AI/OR interface" is largely uncharted, there are also "opportunities" to make mistakes. The kind of work involved is for the more entrepreneurial among us.

I believe that we in mathematical programming have much to learn from studying many of the techniques used in AI. I believe also that we can benefit from the broader modelling traditions of AI.

There are many points of potential commonality. I shall quickly cite a few.

The alpha/beta trees of AI (with node evaluation functions) are a natural extension of the 'or' trees of OR (with linear or combinatorial node relaxations), and may prove the appropriate tool for highly advanced decision-support systems in which competitive reactions are seriously treated.

The "constraint propagation" techniques can be viewed as broad generalizations of our constraint preprocessing routines. These techniques take into account interactions between constraint reformulations and minimally suggest dynamic reformulation in the search tree. These techniques are also relevant to postoptimality analysis in which whole constraints may be added or dropped.

The very broad concept of a "control structure" in AI is a significant extension of the kinds of "swapping" we have considered in large-scale systems, where only a part of a problem can be treated at a time. However, it goes well beyond this issue and includes the possibilities of different processing mechanisms for different aspects of a model, independent of the size issue. The "control structure" orientation subsumes the concept of heuristic strategies for node development in branch-and-bound.

We will stop here with our partial enumeration of commonalities in techniques. Most of AI is not technically oriented, however.

THE "mainstream" of AI is concerned with human and machine cognition, vision, language processing, knowledge representation, and learning, as well as robotics, control structures, etc; basic philosophical issues can arise. These issues will be argued by those with very broad interests.

Certainly, the development of "expert systems" was driven primarily by needs for decision support and not by technical considerations. The "philosophy" of ES is set out in [6]. The emphasis is on knowledge acquisition and representation in specific domains of human expertise for which conventional quantitative models were not deemed appropriate (although, from the above, they can be).

In some respects, ESs resemble a "manual" of information on the domain studied, differing from conventional manuals in the organization and representation of the knowledge and the higher computational complexity of the linkages between "chunks" of knowledge.

The tradition of "knowledge engineering" includes great respect for the wisdom and standards of experts in a domain area. It also includes much patience and care, as well as large allocations of time in developing "prototype" applications. Some of the OR consultants will invest similar amounts of effort in developing a consulting product.

In terms of techniques and methodology the differences between AI and OR may be largely this. Technical OR derives from applied mathematical analysis, linear algebra, graph theory, and axiomatics of combinatorial structures. Technical AI derives largely from applied logic. The remaining differences seem to be details.

HERE are the primary reasons why I believe that a technical focus on inference engines and representation will play a useful and major role in at least the decision-support context:

(1) Knowledge representations, in expert systems or in other "intelligent" systems, need to have adequate inference engines to be used, i.e., good inference engines are a bottleneck: (2) The availability of improved techniques for inference engines and for representations will encourage more ambitious and far-reaching applications; (3) There is evidence to believe (and it is my current belief) that the most respected inference engines for AI (these are predicate-logic-based resolution procedures) will not be as efficient in the less ambitious decision-support context as will be adapttations of OR techniques aided by logic algorithms. (4) I am willing to conjecture that the use of human-protocol based heuristics, such as "means-ends analysis," and other techniques motivated by conscious processing procedures, will lie largely in the control structure of advanced decision support systems. The bulk of the actual processing will be carried out by technical algorithms, many from mathematical programming and many from other branches of applied mathematics.

The enhanced modelling possibilities of the AI tradition, some of which is captured in ESs, is obviously of great attraction to those colleagues in areas like applied OR, industrial engineering, production, marketing, finance, accounting, etc. As many of them slowly turn to AI modelling approaches, they will need our assistance.

Regarding solely the current ES approach within the broad and rich AI traditions, let me make a guess. Limits will be (have been?) found as one deals with human experts who (at best) approximate a reality that has a succinct non-rule-based formulation and who may require thousands of rules to partially represent their knowledge. No simple paradigm will subsume the marvellous complexity of our world.

After all, one would not use an expert system to do linear programming! In fact, Professor Dantzig's own recollection of the origins of our field involve precisely the need to undo some "expert systems" when one finds an excellent mathematical method [4].

Recently I have had a number of conversations with colleagues in OR about software systems which incorporate the multiple features of logic, database, partial knowledge, and linear structure. I find we generally agree about their desirability, but, as one colleague said, "No one knows how to build them." Very bluntly put and (evidently) true. Of course, we can learn how if we choose to.

Acknowledgements:

Anil Nerode first brought to my attention the technological advances of AI in the last several years and recommended a reading of [5].

I have benefitted from discussions with Richard Platek, Janet Kolodner, Arthur Nevins, Andrew Whinston, and Arthur Geoffrion.

Charles Blair's visit was very valuable for me toward clarifying the nature of some inference engines in current use in expert systems.

The image of ESs as complex manuals derived from a conversation with Raj Gupta.

I owe particular thanks to Don Hearn for his willingness to consider a speculative piece for OPTIMA.

Suggestions for Readings

Either [9] or [11] are good general AI texts. In [6] there are nontechnical expositions of the history and philosophy of expert systems and "knowledge engineering" and a detailed application. [6] shows the orientation toward knowledge acquisiton, as opposed to technical issues.

A very fine general logic text is [10].

I strongly recommend [2] for overview articles and for understanding some of the most sophisticated inference engines. [8] goes into more detail on resolution-based theorem proving and can be used in connection with [10]. The text [7] is also very useful.

The dialogues with Teresias in [5] are very instructive, in terms of the kind of decision support available in some expert systems.

[1] is a general reference for the many different approaches to AI.

References

[1] Avron Barr and Edward A. Feigenbaum, *The Handbook of Artificial Intelligence*, Heuris Tech Press and William Kaufman, Inc., Stanford and Los Altos, CA. (vol. I copyright 1981).

[2] W.W. Bledsoe and D.W. Loveland, eds, "Automated Theorem Proving: After 25 Years," Contemporary Mathematics, vol. 29, American Mathematical Society, Rhode Island, 1983.

[3] Robert H. Bonczek, Clyde W. Holsapple, and Andrew B. Whinston, *Foundations of Decision Support Systems*, Academic Press, New York, 1982.

[4] George B. Dantzig, "Reminiscences About the Origins of Linear Programming," Operations Research Letters 1(1982) 43-48.

[5] Randall Davis and Douglas B. Lenat, *Knowldege-Based Systems in Artificial Intelligence*, McGraw-Hill International, New York, 1982.

[6] Frederick Hayes-Roth, Donald A. Waterman, and Douglas B. Lenat, *Building Expert Systems*, Addison-Wesley, Reading, Mass., 1983.

[7] Robert Kowalski, *Logic for Problem Solving*, North-Holland, Amsterdam, 1979.

[8] Donald W. Loveland, *Automated Theorem Proving: A Logical Basis*, North-Holland, Amsterdam, 1978.

[9] Elaine Rich, *Artificial Intelligence*, McGraw-Hill, New York, 1983.

[10] Joseph R. Shoenfield, *Mathematical Logic*, Addison-Wesley, London, 1967.

[11] Patrick Henry Winston, *Artificial Intelligence*, 2nd ed., Addison-Wesley, London, 1984.

CONFERENCE NOTES

Calls for Papers:

Parallel Computing in Optimization
Institut für Informatik
Universität Stuttgart
Stuttgart, Germany F.R.

The increasing number of available computers with a parallel processor architecture requires the development of optimization algorithms which are able to exploit the new technical structures. Thus, it is planned to publish a special volume of *Computing* (Springer) devoted exclusively to the above topic. Papers describing algorithms, software and applications are welcome. They will be refereed in the usual way.

The editors of the special volume are W. Knödel (co-editor of *Computing*) and K. Schittkowski. Three copies of related papers should be sent to one of the editors at the Institut für Informatik, Universität Stuttgart, Azenbergstr. 12, D–7000 Stuttgart 1, Germany F.R.

-K. Schittkowski

12th IFIP Conference on
System Modelling and Optimization
Budapest, Hungary
September 2–6, 1985

The aim of the conference is to discuss recent advances in the mathematical representation of engineering, socio-technical, and socio-economic systems as well as in the optimization of their performances.

Extended abstracts of papers to be presented at the conference should be submitted to the secretariat by January 31, 1985. They should be approximately two pages in length and should describe original unpublished results by their authors.

The conference language is English and typescripts of a selection of complete papers will be published in the Conference Proceedings.

The registration fee will be $80.

Contact:
Dr. J. Szelezsan, John von Neumann Society for Computer Sciences.
Budapest, 5, P.O.B. 240, H-1368
Hungary
Telephone: International +361 113850.

Design and Analysis of Heuristics

This is to announce a special issue of *Management Science* devoted to the *Design and Analysis of Heuristics.* We welcome contributions, both in the form of reviews and new results, on all aspects of this theme, including: (1) design and classification of heuristics; (2) theoretical performance analysis (worst case or probabilistic); (3) empirical performance analysis (computational experiments and case studies).

All submissions will be refereed according to the usual procedure. They should be sent before September 1, 1985 to the Guest Editor for this issue:

Marshall L. Fisher
The Wharton School
University of Pennsylvania
Phildelphia, PA 19104
(215) 898-7721.

Prospective authors are encouraged to discuss the nature of their contributions with the Guest Editor or with the responsible Departmental Editor of *Management Science*:

(January - May 1985)
Alexander H.G. Rinnooy Kan
Department of Industrial Engineering and Operations Research
University of California
Berkeley, CA 94720

-A.H.G. Rinnooy Kan

Cambridge Optimization Symposium
March 21 - 22, 1985

A symposium will be held at Cambridge University on March 21 - 22, 1985, on the development and theory of algorithms for nonlinear optimization calculations. Papers will be presented on recent research, and there will be ample opportunities for information discussions. The speakers will include L.C.W. Dixon (Hatfield Polytechnic), R. Fletcher (University of Dundee), S-P. Han (University of Illinois), M.J.D. Powell (University of Cambridge) and Ph. Toint (University of Namur). Offers to present papers are invited, and the meeting is open to all who give notice that they wish to attend. Please address correspondence to Professor M.J.D. Powell, DAMTP, Silver Street, Cambridge CB3 9EW, who will be pleased to provide further information. This symposium is supported by the London Mathematical Society.

-M.J.D. Powell

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members are all organizers of previous Symposia: E.M.L. Beale, R.W. Cottle, J.-L. Goffin, M. Groetschel, A. Orden, and A. Prekopa.) The Symposium is expected to be self-supporting through its registration fees and institutional subsidies. The Society can lend 'seed money' to the Symposium or, to a limited extent, guarantee it against loss. The host may organize Proceedings of the Symposium as one or more Mathematical Programming Studies. Proceedings were not compiled for all Symposia.)

There are no fixed criteria for the selection of a site. The more important considerations are: technical qualification and enthusiasm of the local staff; adequacy of the meeting facilities; availability of nearby lodging; reasonable travel and local costs -- in short, those factors that will lead to a productive conference that will appeal to a wide range of participants.

We hope that several suggestions for the Symposium site will have been made well in advance of August, 1985 so that the question can be settled at the Society Council meetings to be held in Boston. Interested parties should communicate with the Chairman of the Advisory Committee (Prof. Martin Groetschel, Lehrstuhl fuer Angewandte Mathematik II, Universitaet Augsburg, Memminger Str. 6, D-8900 Augsberg, F.R. GERMANY) or the undersigned as soon as possible on this matter, as well as on the possibility of holding other meetings under the sponsorship of the Society in intermediate years.

Professor Alex Orden
Chairman, Mathematical Programming Society
Graduate School of Business
University of Chicago
1101 E. 58th Street
Chicago, Ill. 60637, U.S.A.

BOOK REVIEWS

Approval Voting
by S.J. Brams and P.C. Fishburn
Birkhäuser, Basel
1983

Approval voting is a method of voting that replaces the familiar habit of the choice of one from among a set of possible candidates with the choice of an "approved" subset of the candidates. No preference among the approved subset is expressed. The winner(s) is (are) the candidate(s) with the most votes.

The idea is fascinating, has been studied axiomatically by various scholars, notably Brams and Fishburn, and has been forcefully advanced by many, in particular Brams, as a kind of best voting system that should replace the plurality system that is so prevelant today. Regrettably, the mathematical results are not in themselves compelling as a support to that contention. On the other hand, plausible arguments and reconstructions of past elections do lend strong credence to the advantageous properties of approval voting, and one can hope for further axiomatic results that would provide a solid foundation for that claim.

The book itself is essentially a collection of the papers of Brams and Fishburn, including definitions and the statements of theorems, but excluding proofs and including the plausible arguments and reconstructions. Although a convenient source for mathematical readers interested in the subject, the absence of proofs is a serious hindrance. Nonmathematical readers will have as much trouble with some of the book as with a mathematics text because the definitions and theorems are stated in the usual mathematical style to which we are all accustomed. With this choice of quasi-mathematical presentation, the book disappoints both the mathematically trained reader and the nonmathematically trained. This is a pity, for the topic is important and the book contains a wealth of interesting results and discussion.

The subject of approval voting has nothing directly to do with mathematical programming or optimization.

M.L. Balinski

Generalized Concavity in Optimization and Economics
Edited by S. Schaible and W.T. Ziemba
Academic Press, London
1981
ISBN 0-12-621120-5

This book consists of papers on two strongly-connected topics of mathematical programming: generalized convexity and fractional programming. Since 1949 numerous authors have defined over 20 classes of generalized convex functions which have a wide variety of applications. Therefore, the publication of a collection of papers about this topic is of great interest.

The published contributions are surveys of current knowledge and describe new research results. The relations to the theory of duality and to stochastic systems and applications in management science and economics especially are considered.

The papers are divided into seven sections:

1. Characterizations of Generalized Concave Functions, 2. Generalized Concave Quadratic Functions and C^2-Functions, 3. Duality for Generalized Concave Programs, 4. New Classes of Generalized Concave Functions, 5. Fractional Programming, 6. Applications of Generalized Concavity in Management Science and Economics, and 7. Applications to Stochastic Systems.

K.-H. Elster

Mathematical Programming
Edited by R.W. Cottle, M.L. Kelmanson and B. Korte
North-Holland, Amsterdam
1984
ISBN 0-444-86821-6

There are 21 papers in this proceedings of the International Congress on Mathematical Programming, Rio de Janeiro, Brazil, April 6–8, 1981. They cover an impressive variety of topics: linear programming, integer programming, graph theory, networks, matroids, scheduling, nonlinear programming, complementarity, complexity and functional analysis. The book contains also Professor George B. Dantzig's personal memoire "Reminiscences about the Origins of Linear Programming." Most of the papers are theoretical, including surveys with very complete lists of references, but there are some applied articles. The quality of the papers is good.

Practitioners may find some reports stimulating for their own job, however, many of the theoretical papers require quite a bit of mathematical knowledge, so this book will be mainly of interest to researchers in the field of mathematical programming and its periphery.

S. Walukiewicz

Microsolve/Operations Research: An Introduction to Operations Research with Microcomputers
by P.A. Jensen
Holden Day, Inc.
1983
ISBN 0-8162-4501-0

The book describes several codes on two included disks which provide a motivating and illustrating supplement to an introductory course on operations research. The book is written mainly as a manual containing brief introductions to the considered problems and proposing a series of examples for application of the codes. Some examples are included as data files on the disks.

The program disk contains codes for linear programming, network flow programming, 0-1 programming, dynamic programming, queue simulation, birth-death processes and markov chains.

All codes run under the disk BASIC language of the IBM personal computer with 64K of RAM memory, and at least one disk drive using PC DOS 1.1. The choice of BASIC may be questioned though motivated by its simplicity and widespread availability. Nowadays, all standard computer languages are available for micros and a more structured language, e.g. PASCAL, may be preferred for university level teaching. The slow performance of the BASIC interpreter causes no problem when the programs are used for modeling purposes. For solving some of the provided examples or user-supplied moderate-sized problems, one should use compiled versions of the programs which run faster by a factor up to 10. To enable compilation by the IBM BASCOM compiler for most of the programs, only some minor modifications were necessary.

For linear programming a nice model generator allows easy input and modification of data. Such an interactive tool is very helpful when teaching modeling in small groups or when preparing examples for lectures. The LP-code implements the bounded revised simplex method which may suffice on an introductory level and which can be used to illustrate numerical difficulties. Interactive choice of pivot steps differing from the

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proposed standard strategy is possible. Sensitivity analysis is optional.

For network programming a helpful model generator is provided too. From the computational point of view, the implemented primal simplex method for solving quite general transshipment problems is the most sophisticated code of the package. Implementation is closely oriented along the lines of the textbook of Jensen and Barnes on network flow programming. Without that book a user will hardly appreciate the details of the iteration display (may be suppressed by user).

For 0-1 programming the additive method is implemented. Data can be easily generated using the LP model generator. Clearly, only small-sized problems may be solved.

For dynamic programming a rather general approach is used. A main program implements the different general solution techniques. For concrete applications the user must supply a set of specific subroutines. Included are subroutines for knapsack problems, special path problems, replacement problems, capacity expansion problems, deterministic inventory problems, and linear staged problems. The subroutines are quite simple and do not support generating, modifying, or saving of user supplied data. For small problems a nice graphical display illustrates the performance of the chosen solution technique.

Methods for the analysis of some stochastic models are implemented in the remaining three codes. A multichannel queue with up to 5 servers is simulated and graphically displayed for user supplied data describing the random structure of arrival and service times. For general birth-death processes state probabilities and statistical data can be calculated from arrival (birth) and departure (death) data. For markov chains, the code again supports generating, modifying and saving of data. Simulation of markov processes as well as calculation of transient states and state probability vectors are implemented.

For introductory courses on operations research, in particular when modeling is emphasized, the use of the program package may be recommended for illustrative purposes or for preparing examples. Small courses and sufficient equipment with micros are indispensable prerequisites for effective use in class.

-Dr. U. Zimmermann

Notes on Introductory Combinatorics
by G. Pólya, R.E. Tarjan and D.R. Woods
Birkhäuser, Boston-Basel-Stuttgart
1983
ISBN 0-8176-3123-2

In 1978, George Pólya and Bob Tarjan taught an introductory course on combinatorics at Stanford University. Their teaching assistant Donald Woods prepared the class notes that resulted in this book. The first two-thirds of the course dealt with *enumerative* combinatorics, including combinations and permutations, generating functions, the principle of inclusion and exclusion, Stirling numbers and Pólya's theory of counting. The last third covered *existential* and *algorithmic* combinatorics, including stable marriages, cardinality matching, network flow, Hamiltonian and Eulerian paths, and planarity.

The book gives a broad sample from the entire area of combinatorics on a very elementary level and in a very informal way. I taught a course from it last year to undergraduates in an area somewhere between business administration and computer science. I enjoyed it and I look forward to using the book again next year.

Still, there are some difficulties. These are due mainly to the fact that the presentation is too sloppy and not well-structured enough. I will give two specific examples. Either I do not understand much about Ramsey theory, or most of the 'eithers' in Chapter 9 should disappear -- or both, of course. In the chapter of Pólya's theory of counting, after 13 pages of unmotivated computations of cycle indices, the main theorem is stated without proof: "You can't eat mathematics, but you *can* digest it. So let's chew on a few examples." I find this hard to swallow. I do not object to the deletion of the proof, but what may have worked at the blackboard does not work here in print due to lack of motivation and structure. It is a charming little book. To make it an outstanding little book, it needs one more round of rewriting.

Finally, the typographical presentation is an insult to prospective readers. The most disturbing aspect of such instances of computerized typography is that we are being conditioned to accept them.

-J.K. Lenstra

Computer Scheduling of Public Transport
by A. Wren
North-Holland, Amsterdam, 1981
ISBN 0-444-86170-x

The chapters are papers based on presentations at the International Workshop at Leeds in 1980. A wide variety of methods to solve bus and crew scheduling by computer is described.

Some general papers which survey the state of the art and the experiences with implemented scheduling problems are followed by the chapters containing more detailed information.

The two main problematic areas concerning bus and crew scheduling have been subdivided further by the editor into generation of times of bus trips, route-based construction of bus schedules, network-based construction of bus schedules, bus crew scheduling, formation of rotating rosters, and miscellaneous papers. But many authors discuss more than one of these areas.

To solve the optimization problems the authors use heuristic methods and mathematical methods, like mathematical programming, which in theory would guarantee optimal solutions. In some cases the solution can be found by interactive methods.

The chapter including the glossary of terms is very useful for understanding the papers.

-G. Gershner

Studies on Mathematical Programming
Edited by A. Prekópa
Akadémiai Kiadó, Budapest, 1980
ISBN 963-05-1854-6

This volume contains 15 papers presented at the Third Conference on Mathematical Programming held at Matrafüred, Hungary, in February 1975. The authors have summarized not only their own results but also those of other researchers. There are contributions to almost all parts of mathematical programming, especially linear, nonlinear, discrete, parametric and stochastic programming.

Because the conference took place almost 10 years ago, all papers are no longer up to date. It is a pity that so much time passed before publication of this material.

-J. Piehler

Linear Optimization and Approximation
by K. Glashoff and S.-A. Gustafson
Applied Mathematical Sciences, Vol. 45
Springer-Verlag, Berlin
1983
ISBM 3-540-90857-9

The authors of this book are well-known for their important theoretical and practical contributions to the field of semi-infinite programming. The book greatly differs in many respects from other existing books on linear optimization and approximation. Its main message is that semi-infinite linear programming is an extension of ordinary linear programming having the benefits of allowing for a broader field of applications at the cost of only little additional work. This concept mainly influences the treatment of duality theory which occupies a large part of the book. For reasons of greater clarity the presentation mainly relies on geometrical concepts. It is a characteristic feature of the book that it makes no reference at all to the theory of convex polyhedra (neither the terms "polyhedren" or "Polytope" or even "simplex" nor the names of Rockafellar or Grunbaum occur in the index). This is due to the semi-infinite nature of the presentation.

One chapter is devoted to weak duality including some elementary observations on duality state diagrams and duality gaps. It is shown how these rather simple results can be applied in the theory of uniform approximation. In the following chapter the strong duality theorems are derived. It is a remarkable new feature of semi-infinite programming as compared with ordinary linear programming that duality gaps can occur. Strong duality theory for semi-infinite programming provides conditions guaranteeing that these gaps cannot happen. It turns out that these conditions are quite natural in requiring that the problem should be formulated properly.

The algorithmic part of the book is completely devoted to the simplex algorithm and its adaption to semi-infinite problems and implementation on a computer. Specifically, the task of "stable" implementation of the basic exchange step is treated in greater detail. In contrast to most books on linear programming, no "simplex tableaux" are used in the text. These tableaux come from those times when students in linear programming did their exercises manually. They are rather misleading and obscure the facts behind this concept. This part of the book demonstrates clearly that the authors are numerical analysts having actual numerical experiences. For solving the semi-infinite programming problem an algorithm consisting of three phases is proposed. In the first phase the infinite number of restrictions of the underlying problem is replaced by a finite subset (discretization) and the resulting ordinary linear programming problem is solved by the ordinary simplex method. The optimal solution of the discretized problem yields structural information about the optimal solution of the semi-infinite problem in that it provides a guess for the number of dual variables which are nonnegative for the latter. In the last phase a nonlinear system of equations is derived from the optimality conditions by means of this structural information. This system is solved numerically using Newton's method. In numerous applications which were published by the authors in different articles, this approach turned out to be extremely efficient especially for numerically sensitive problems, as they are quite common in mathematical applications of semi-infinite programming.

A special mathematical application is treated in the chapter on approximation by Chebychev systems. Of great practical importance for numerical approximation, the structure of the optimal solution is known in advance.This simplifies greatly the numerical algorithm.

In the last chapter some applications are presented. These cover the topics of optimal control with distributed parameters, operator equations of monotonic type, and air pollution abatement problems.

The book is written for mathematicians. Therefore, the presentation is mathematically rigorous. The problems treated are from rather mathematical applications and are influenced greatly by approximation problems. Nevertheless, the presentation is made as simple as possible by using a clear and didactic approach. Many exercises and worked-out examples facilitate the application of the results.

The book can be recommended as a textbook for students of mathematics and for all mathematicians interested in this field.

-U. Eckhardt

Combinatorial Methods of Discrete Programming
by L.B. Kovács
Akadémiai Kiadó, Budapest, 1980
ISBN 963-05-2004-4

This is partly a textbook and partly a monograph. The first chapter is an introduction to the models and problems of integer programming, and the chapters that follow discuss several types of algorithms: Implicit enumeration, branch-and-bound and dynamic programming. Later chapters give some of the author's new results with respect to further development of existing algorithms, new procedures, heuristic methods, combinations of different algorithms and some theoretical research. Because of the combinatorial character of the book, cutting plane methods are not included. The last chapter gives a survey on recent directions in discrete programming with extensive references to the literature from 1974 to 1979. The book does not contain any results in computational complexity even though this topic is one of the most important developments of recent years in discrete programming. For this the reader must be referred to other books.

Nevertheless, this is a useful book for those who want to acquaint themselves with this part of mathematical programming. Specialists too will get some valuable suggestions and new ideas.

-J. Piehler

Handbook of Mathematical Economics
Volume 1, 1981; Volume 2, 1982
Edited by K.J. Arrow and M.D. Intriligator
North-Holland, Amsterdam
ISBN 0-444-06054-1

The Handbook appears as the first book in the series of handbooks in economics, the aim of which is to provide comprehensive and self-contained surveys of the current state of various branches of economics. The Handbook surveys, as of the late 1970's, the state of the art of mathematical economics. It includes 29 chapters arranged into five parts and published in three volumes.

Volume 1 coincides with Part 1, which treats Mathematical Methods in Economics, preceded by a brief historical introduction. Volume 2 comprises Part 2 elaborating on Mathematical

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Approaches to Microeconomic Theory and Part 3 dealing with Mathematical Approaches to Competitive Equilibrium. Volume 3, which is to appear, contains the remaining two parts which cover Mathematical Approaches to Welfare Economics and Mathematical Approaches to Economic Organization and Planning.

Though each of the chapters can be read independently, the Handbook can assist researchers and students working in one branch of mathematical economics to become acquainted with other branches of the field. Most of the topics presented are treated at an advanced level suitable for use by researchers or by advanced graduate students in both economics and mathematics.

-M. Valch

Chemical Applications of Topology and Graph Theory
Studies in Physical and Theoretical Chemistry 28
Edited by R.B. King
North-Holland, Amsterdam
1983

Every graph theorist knows that there are some applications of graph theory to chemistry. To see how many there are and to appreciate the variety of applications of numerous branches of graph theory (and topology and geometry) to chemistry, he should read this collection of papers. To give a glimpse of the type of applications that are discussed, I would like to mention the following paper titles and catchwords: symmetry and spectra of graphs and their chemical applications, chemical interpretation of graph theoretical indices, global dynamics of a class of reaction networks, the use of Riemannian surfaces in the graph-theoretical representation of Möbius systems, the automorphism groups of some chemical graphs.

It seems to me that the contacts between graph theorists and chemists have not been too close in the past. Graph theoretic concepts well-known in graph theory have been reinvented by chemists, and vice versa, again and again. Parameters of interest for chemists have been neglected by graph theorists and these - in turn - often have not been able to "sell" new theories and results which have potential applications in chemistry to the chemists. A paper collection (and a symposium) of this type is valuable in many respects. It gives chemists the chance to introduce their models to graph theorists and to obtain help from the specialists in this field. Such cooperations may result in better chemical models, and furthermore, additional insights may be obtained by treating the models with other (or better or new) methods of graph theory. For the graph theorists such a book provides a good opportunity to get into closer contact with important real-world applications and possibly a stimulus for further research in application-oriented areas of graph theory.

-M. Grötschel

JOURNALS & STUDIES

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College Park, Maryland 20742

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C A L E N D A R

This Calendar lists noncommercial meetings specializing in mathematical programming or one of its subfields in the general area of optimization and applications, whether or not the Society is involved. (The meetings are not necessarily 'open'.) Any one knowing of a meeting that should be listed here is urged to inform Dr. Philip Wolfe, IBM Research 33-2, POB 218, Yorktown Heights, NY 10598, U.S.A; Telephone 914-945-1642, Telex 137456.

Some of these meetings are sponsored by the Society as part of its world-wide support of activity in mathematical programming. Under certain guidelines the Society can offer publicity, mailing lists and labels, and the loan of money to the organizers of a qualified meeting.

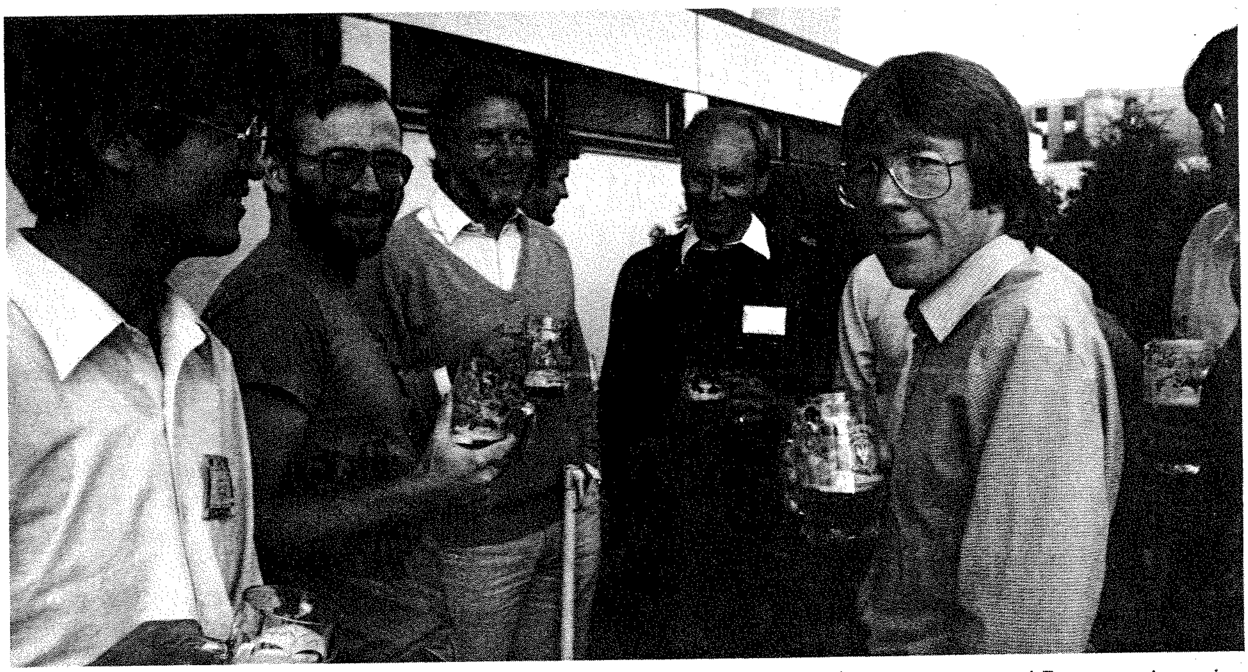
Substantial portions of meetings of other societies such as SIAM, TIMS, and the many national OR societies are devoted to mathematical programming, and their schedules should be consulted.

1985

May 6-10: Journées Fermat: "Mathematiques pour l'optimisation", Toulouse, France. Contact: Prof. J.B. Hiriart-Urruty, Laboratoire d'Analyse Numérique, Université Paul Sabatier, 118, Route de Narbonne, 31062 Toulouse Cedex, France. Telephone (61) 55-66-11.

June 11-14: 5th IFAC Workshop on Control Applications of Nonlinear Programming and Optimization, Capri, Italy. Contact: Professor G. Di Pillo, Dipartimento di Informatica e Sistemistica, Università degli Studi di Roma 'La Sapienza', Via Eudossiana 18, 00184 Roma, Italy. Telephone (39) 6-484441.

August 5-9: Twelfth International Symposium on Mathematical Programming in Cambridge, Massachusetts, U.S.A. Contact: Professor Jeremy Shapiro, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, MA 02139, U.S.A. Telephone 617-253-7165. Official triennial meeting of the MPS.



Farewell at Bad Windsheim Participants at the NATO ASI on Computational Mathematical Programming enjoy a barrel of beer at the farewell party. The conference was held July 23 to August 2, 1984 at Bad Windsheim, Germany F.R. Left to right: Y.Yuan, J. Burke, R. Wets, B. Mifflin (background), D. Kraft and P. Gill. Photo by A. Idnani.

Gallimaufry

Narendra Karmarkar (AT&T Bell Laboratories) delivered a special plenary seminar on his new linear programming method at the ORSA/TIMS Dallas meeting in November. The session was attended by over 1000 and received considerable coverage by the Dallas press and TV. . . . **Michael Ball** (Maryland) is visiting the Departments of Combinatorics and Optimization and Management Sciences at the University of Waterloo during the 1984-85 academic year. . . .**George L. Nemhauser** will be a visiting professor at Georgia Tech during the 1985-86 academic year. . . The Committee on Algorithms has initiated a system to match traveling lecturers with institutions interested in inviting speakers. The system covers the entire world. It is being computerized by **Ashok Idnani**, Computer Science Department, Pace University, Pleasantville, New York 10570. He may be contacted for further information. . . .The Sixth Mathematical Programming Symposium, Japan will be held in Tokyo November 7-8, 1985. Contact **Masao Iri**, Faculty of Engineering, University of Tokyo, Bunko-Ku, Tokyo 113 or **Hiroshi Konno**, Tokyo Institute of Technology, Meguro-Ku, Tokyo 152.

Deadline for the next OPTIMA is May 1, 1985.

OPTIMA
MATHEMATICAL PROGRAMMING SOCIETY NEWSLETTER

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.

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, W. Germany.

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