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OPTIMA

Mathematical Programming Society Newsletter

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‘Set’less Collections of SET Cards

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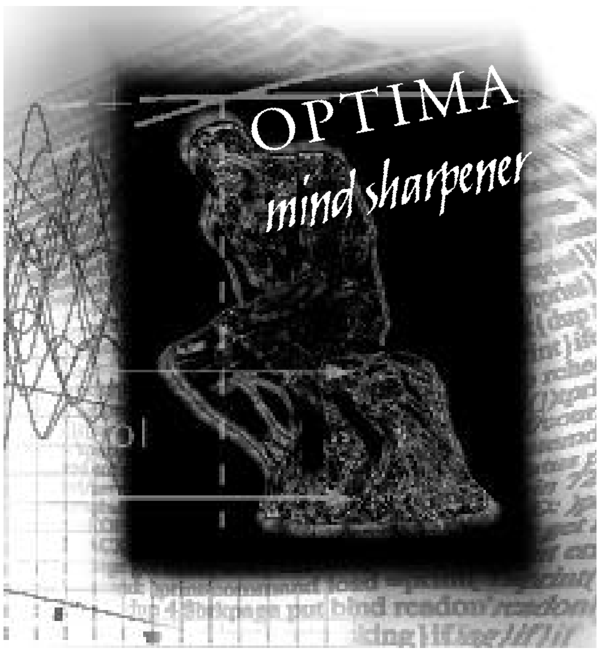
We invite OPTIMA readers to submit solutions to the problems to Robert Bosch (bobb@cs.oberlin.edu). The most attractive solutions will be presented in a forthcoming issue.



‘Set’less Collections of SET Cards

Robert A. Bosch
August 29, 1999

SET is a card game played with a special 81–card deck.[1] Each SET card has four attributes (number, color, shading, and shape), and on each card, each attribute assumes one of three possible values. More precisely, a SET card displays a drawing of one, two, or three symbols. The symbols are all red, green, or purple; filled-in, outlined, or striped; oval-shaped, squiggle-shaped, or diamond-shaped. The SET deck contains 3^4=81 cards, one for each possible combination of attribute values.

The basic object in SET is the ‘Set,’ a collection of three cards that has, with respect to every attribute, either all or none of its cards in agreement. At the beginning of the game, the deck is shuffled and twelve cards are laid out on the table, face up. The first player to spot a ‘Set’ removes it, placing it in his or her pile. Then three more cards are placed on the table, and play continues. Note that the cards displayed in Figure 1 form a ‘Set’: all of them agree with respect to color, and none of them agree with respect to number, shading, or shape.

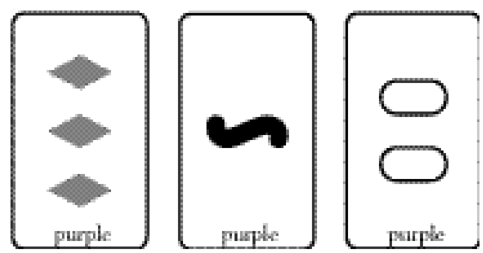


Figure 1. Three set cards that form a ‘Set’

The rulebook states “If all players agree that there is no ‘Set’ in the twelve cards showing, three more cards (making a total of fifteen) are laid face up. These cards are not replaced when the next ‘Set’ is picked up, reducing the number to twelve again.” The implication is that every collection of fifteen cards contains at least one ‘Set.’ This is not true. In fact, it is easy to find collections of fifteen cards that are ‘Set’less (i.e. contain no ‘Sets’).

In December 1996, Rajmohan Rajagopolan—then an undergraduate student at Oberlin College, and now a graduate student at Cornell University—realized that integer programming could be used to find a largest ‘Set’less collection of SET cards. Rajagopolan treated each SET card as a point in S^4, where S is the set {0,1,2}. There are many ways that this can be done; one possible ‘encoding’ is given in Figure 2. Note that the cards corresponding to three distinct points $\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{z}$ S^4 form a ‘Set’ if and only if $(x_i + y_i + z_i)$ mod 3 = 0 for i =1,2,3,4.

[1] SET is a registered trademark of Set Enterprises Inc. (http://www.setgame.com/).

c_1 – number	one	0	c_2 – color	red	0
	two	1		green	1
	three	2		purple	2
c_3 – shading	filled-in	0	c_4 – shape	oval	0
	outlined	1		sqiggle	1
	striped	2		diamond	2

Figure 2. Mapping a card to a point $\boldsymbol{c} = (c_1, c_2, c_3, c_4) \in S^4$

Rajagopolan's integer program for finding a largest 'Set'less collection is quite simple:

$$\begin{array}{lll} \max & \sum_{x \in S^4} v_x & \\ \text{s.t.} & v_x + v_y + v_z \le 2 & x, y, z \in S^4: x, y, z \text{ are distinct, and} \\ & & (x_i + y_i + z_i) \bmod 3 = 0 \text{ for } i = 1,2,3,4. \\ & v_x \in \{0,1\} & x \in S^4. \end{array}$$

There are 81 binary variables, one for each SET card (each $\boldsymbol{x} \in S^4$). The variable v_x is assigned the value 1 if and only if the card corresponding to $\boldsymbol{x}$ is placed in the 'Set'less collection. There are $\binom{81}{2}/3 = 1{,}080$ constraints, one for each 'Set.' They ensure that no more than two of the three cards that form a 'Set' are placed in the collection.

In June 1997, I attempted to solve Rajagopolan's integer program using branch and bound (version 4.0.9 of CPLEX's Mixed Integer Optimizer). After fixing four variables at their upper bounds of one, I started the optimization process. Within a few seconds, CPLEX had discovered a feasible solution with objective value 20. At this point, the upper bound on the optimal value of the objective function was 35.0, and the branch-and-bound tree consisted of 1,382 nodes, of which 878 were unexplored. Approximately 0.4 MB of memory were being used to store the branch-and-bound tree.

An hour later, branch and bound was still going. The best solution it had found so far was the one with objective value 20. The upper bound on the optimal value of the objective function was now 25.5. The branch-and-bound tree had over 350,000 nodes, and over 200,000 of these nodes were unexplored. Slightly more that 100 MB of memory were tied up in the storage of the branch-and-bound tree! At this point, I terminated the search.

In September 1997, one of my colleagues, Oliver Schirokauer, reported to me that he and Carl Cotner had written a clever program that used enumeration to prove that a 'Set'less collection of SET cards can contain no more than 20 cards. After learning from Schirokauer that I could have fixed six (carefully chosen) variables at their upper bounds of one, I gave CPLEX another try. This time, CPLEX was successful, solving Rajagopolan's integer program in approximately 1,500 seconds and almost 275,000 branch-and-bound nodes.

Problems

Interested readers may enjoy trying to solve the following problems:

1. Find valid inequalities for Rajagopolan's integer program. ***Note:*** When one additional inequality was added, CPLEX was able to solve the resulting integer program in approximately 800 seconds, with just over 118,000 branch-and-bound nodes. When an extra 1,170 inequalities—all of the same type—were added, CPLEX took approximately 650 seconds, with just under 3,500 nodes! ***Hint:*** SET can be played with certain 9-card decks (the purple squiggles, for instance).
2. In a well-known paper on cutting planes [1], Vasec Chvátal presented an integer programming formulation (and a cutting-plane proof of the solution of) Moser's Cube Problem:

   Let us consider the three-dimensional tick-tack-toe cube with 27 points (0,0,0), (0,0,1), …, (2,2,2). Our objective is to select as many of these 27 points as possible without choosing three collinear ones.

   The problem of finding a largest 'Set'less collection of purple SET cards (a 27-card deck) is a variant of Moser's Cube Problem. Each 'Set' can be thought of as a line. (Just as two points determine a line, two SET cards determine a 'Set.') Construct a cutting-plane proof that a 'Set'less collection of SET cards can contain at most nine purple cards.
3. Suppose that each SET card has five attributes instead of four. Determine the largest number of cards in any 'Set'less collection of cards.

Maximizing Vitality Revisited

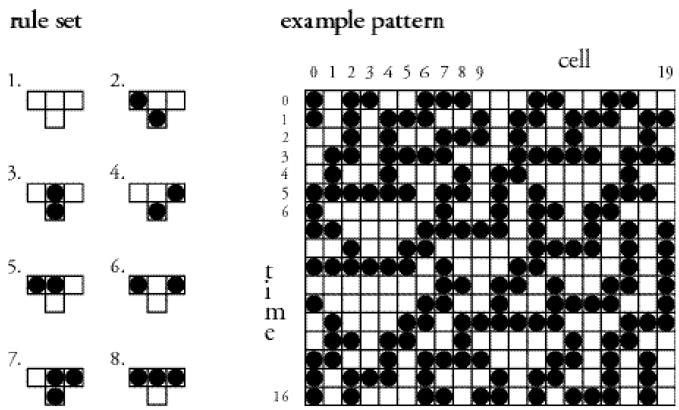


Figure 3. The rule set and an example pattern

In the March 1999 issue of OPTIMA, we discussed a simple one-dimensional cellular automaton that consists of n cells (numbered from 0 to n-1 going from left to right) arranged in a horizontal line. Each cell i has two neighbors: a left neighbor $l(i)$ and a right neighbor $r(i)$. Cell 0's left neighbor is cell n-1, and cell n-1's right neighbor is cell 0.

Recall that at each point in time, each cell is either alive or dead. To start up the cellular automaton, we just need to decide which cells will be alive at time $t=0$ and which ones will be dead then. Then to run it, we simply apply the rule set (displayed on the left side of Figure 3) over and over again. The first application of the rule set determines the states of the cells at time $t=1$. The second application determines the states of the cells at time $t=2$. And so on. In the example pattern (displayed on the right side of Figure 3), cell 0 is alive at time 1 because of rule 3, which states that if cell i is alive at time t and cells $l(i)$ and $r(i)$ are dead at time t, then cell i must be alive at time $t+1$. Cell 1 is dead at time 1 due to rule 6, and cell 2 is alive at time 1 due to rule 7.

At the end of the March 1999 article, we challenged readers to solve three problems. The first was to complete our integer programming formulation of the maximum average vitality problem, the problem of finding an initial assignment of states to cells that maximizes the average vitality of the cellular automaton over a given time interval $[a,b]$. (The vitality of a cell over a time interval is the fraction of the time it is alive; the average vitality of the cellular automaton over a time interval is the average of all its cells' vitalities over that time interval.) Our integer program had a binary variable

$$x_{i,t} = \begin{cases} 1 & \text{if cell } i \text{ is alive at time } t, \\ 0 & \text{if not} \end{cases}$$

for each $0 \le i \le n$-1 and each $0 \le t \le b$. We presented two constraints:

$$-x_{l(i),t} - x_{i,t} - x_{r(i),t} + x_{i,t+1} \le 0 \qquad \begin{array}{c|ccc|l} & l(i) & i & r(i) & \\ t & -1 & -1 & -1 & \le 0 \\ t+1 & & 1 & & \end{array}$$

and

$$x_{l(i),t} + x_{r(i),t} + x_{i,t+1} \le 2. \qquad \begin{array}{c|ccc|l} & l(i) & i & r(i) & \\ t & 1 & 0 & 1 & \le 2 \\ t+1 & & 1 & & \end{array}$$

The former enforces rule 1 for cell i during the transition from time t to time $t+1$; the latter enforces rules 6 and 8. Each constraint works by prohibiting the configuration that violates the rule.

Leslie Gardner submitted constraints that enforce rules 2-5 and 7 for cell i during the time-t-to-time-t+1 transition:

$$x_{l(i),t} - x_{i,t} - x_{r(i),t} - x_{i,t+1} \le 0, \qquad \begin{array}{c|c|c|c|} & l(i) & i & r(i) \\ \hline t & 1 & -1 & -1 \\ \hline t+1 & & -1 & \\ \end{array} \le 0$$

$$-x_{l(i),t} + x_{i,t} - x_{r(i),t} - x_{i,t+1} \le 0, \qquad \begin{array}{c|c|c|c|} & l(i) & i & r(i) \\ \hline t & -1 & 1 & -1 \\ \hline t+1 & & -1 & \\ \end{array} \le 0$$

$$-x_{l(i),t} - x_{i,t} + x_{r(i),t} - x_{i,t+1} \le 0, \qquad \begin{array}{c|c|c|c|} & l(i) & i & r(i) \\ \hline t & -1 & -1 & 1 \\ \hline t+1 & & -1 & \\ \end{array} \le 0$$

$$x_{l(i),t} + x_{i,t} + x_{i,t+1} \le 2, \qquad \begin{array}{c|c|c|c|} & l(i) & i & r(i) \\ \hline t & 1 & 1 & 0 \\ \hline t+1 & & 1 & \\ \end{array} \le 2$$

$$-x_{l(i),t} + x_{i,t} + x_{r(i),t} - x_{i,t+1} \le 1. \qquad \begin{array}{c|c|c|c|} & l(i) & i & r(i) \\ \hline t & -1 & 1 & 1 \\ \hline t+1 & & -1 & \\ \end{array} \le 1$$

Gardner also solved the second and third problems. The second problem was to prove that the maximum average vitality v(a,b) of the cellular automaton over the time interval [*a*,*b*] satisfies

$$v(a,b) \le \frac{3}{5} + \frac{2}{5(b-a+1)}.$$

Gardner began her proof by proving the validity of the following inequality:

$$x_{l(i),t} + x_{i,t} + x_{r(i),t} + x_{i,t+1} + x_{r(i),t+1} \le 3. \qquad \begin{array}{c|c|c|c|} & l(i) & i & r(i) \\ \hline t & 1 & 1 & 1 \\ \hline t+1 & & 1 & 1 \\ \end{array} \le 3$$

(To prove that it holds, take the inequality $-x_{i,t} < -1$ and add to it the two inequalities that enforce rule 5 at cell *i* and cell *r*(*i*) during the time-*t*-to-time-*t*+1 transition.) She then summed up all copies of this inequality for *i* between 0 and *n*-1 and *t* between *a* and *b*, obtaining

$$3\sum_{i=0}^{n-1} x_{i,a} + 5\sum_{i=0}^{n-1}\sum_{t=a+1}^{b-1} x_{i,t} + 2\sum_{i=0}^{n-1} x_{i,t} \le 3(b-a)n.$$

From this it follows that

$$5\sum_{i=0}^{n-1}\sum_{t=a}^{b} x_{i,t} \le 3(b-a)n + 5n$$

and

$$v(a,b) = \frac{1}{(b-a+1)n}\sum_{i=0}^{n-1}\sum_{t=a}^{b} x_{i,t} \le \frac{3(b-a)n+5n}{5(b-a+1)n} = \frac{3}{5} + \frac{2}{5(b-a+1)}.$$

The third problem asked for a solution strategy that would exploit the fact that once values have been assigned to the variables for time 0, the values of the remaining *nb* variable are completely determined. (Once we know the values of the time-0 variables, we can run the cellular automaton to obtain the values of the remaining variables.) Gardner suggested "… a genetic algorithm approach where the chromosomes are sequences of the n binary variables for time 0." The fitness of a chromosome would be the resulting average vitality. Simple crossover could be used as the genetic operator.

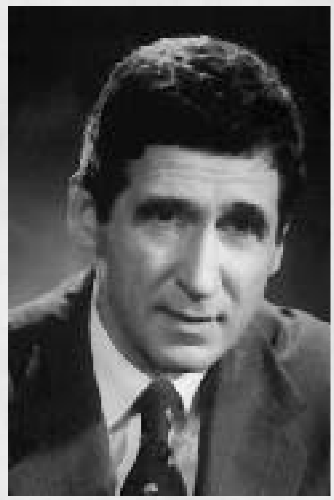
References

[1] V. Chvátal, *Edmonds polytopes and a hierarchy of combinatorial problems*, Discrete Mathematics 4 (1973), pp. 305-337.

Birthdays

OPTIMA wants to congratulate our distinguished colleagues on their birthdays!

GEORGE B. DANTZIG celebrated his 85th birthday. A special "*Dantzig Fest*" was organized at the INFORMS National Meeting in Philadelphia, Nov. 7-10, 1999, including presentations by Arthur F. Veinott, B. Curtis Eaves, Irv Lustig, Allan J. Hoffman, Ellis L. Johnson, and George B. Dantzig himself.



RALPH E. GOMORY received as a "birthday present," the ***DIMACS Workshop on the Theory and Practice of Integer Programming in honor of Ralph E. Gomory on the Occasion of his 70th Birthday***, organized by Bill Cook and Bill Pulleyblank. The workshop was organized at IBM, Yorktown Heights, on Aug. 2-4, 1999. Main speakers were Vasek Chvatal, Herbert E. Scarf, Egon Balas, George L. Nemhauser, Gerard Cornuejols, and Ralph E. Gomory.

JOHN E. DENNIS, JR. – our previous chairman, and current vice-chairman – celebrated his 60th birthday, and received a dedicated issue of ***SIAM Journal on OPTIMIZATION***, a journal of which he was the first editor. The dedication written by Michael L. Overton and Robert B. Schnabel can also be found at the following URL: http://epubs.siam.org/sam-bin/dbq/article/94709

SOCIETY NEWS

ISMP XVII

The 17th International Symposium on Mathematical Programming (ISMP 2000) will take place in Atlanta, Georgia, USA, on the campus of the Georgia Institute of Technology August 7-11, 2000. For more information, please visit the web site (http://www.isye.gatech.edu/ismp2000/).

Nominations for 2000 Elections

The Constitution of the Mathematical Programming Society sets the terms of office for all officers of the Society at three years. Elections for all offices (Chair, Treasurer, and four At–Large Members of Council) are to be held four months prior to each triennial International Symposium. The seventeenth symposium will take place in Atlanta on August 7–11, 2000, so the next election will be held in April 2000. The new Members–at–Large of the Council will take office at the time of the symposium, the Chair–Elect and the Treasurer–Elect will take office one year later.

Candidates must be members of the Society and may be proposed either by Council or by any six members of the Society. No proper nomination may be refused, provided the candidate agrees to stand. The following procedure will be observed:

(1) Nomination to any office is to be submitted to the Nomination Committee, which consists of John Dennis, Jan Karel Lenstra (chair, jkl@win.tue.nl), and Clyde Monma. Such nomination is to be supported by the nominator and at least five other members of the Society.

(2) In keeping with tradition, the next Chair should preferably be a North American resident. The membership is asked to consider no residents from other continents as candidates for the Chair.

(3) When the ballots are counted, the four At–Large candidates for Council having the highest number of votes will be elected; however, no more than two members having permanent residence in the same country may be elected.

–JEAN-PHILIPPE VIAL, CHAIR

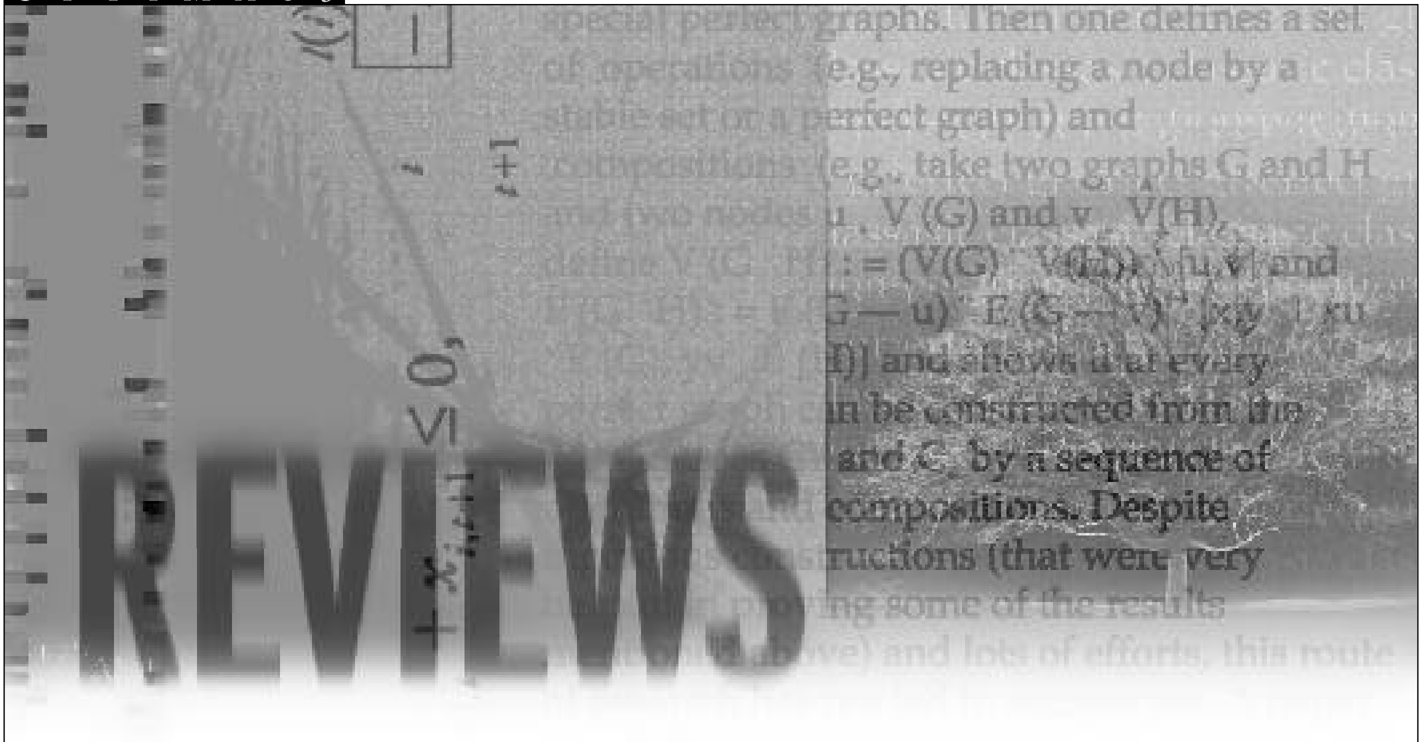
Over $35,000 Collected for Fulkerson Prize

The Fulkerson Prize for outstanding papers in discrete mathematics is sponsored jointly by the Mathematical Programming Society and the American Mathematical Society. Since 1979, up to three awards were presented at each International Symposium on Mathematical Programming. The awards were initially paid out of a memorial fund that was established by friends of the late Delbert Ray Fulkerson to encourage mathematical excellence in the fields of research exemplified by his work.

The prize fund became depleted several years ago. MPS and AMS appointed a fund-raising committee, consisting of Bob Bixby, Bob Bland, and Ron Graham. In the past year, with the help of Steve Wright and Jan Karel Lenstra, they raised a total amount of $35,697.32, which should be sufficient to support the prize in perpetuity. The new prize fund will be administered by MPS.

Substantial corporate and institutional donations were received: **Foundation 14th ISMP (Amsterdam, 1991), $3,800; IBM, $5,000; Lucent Technologies, $5,000; Philips Research Laboratories, $3,000; Telcordia Technologies (formerly Bellcore), $5,000.** These sponsors will be recognized on the MPS web site.

Individual contributions were made by **Bob Bixby, Ralph Gomory, William Hogan, Clyde Monma, George Nemhauser, Lloyd Shapley, Irene and Richard Van Slyke, David Weinberger, Karen Aardal, Anant Balakrishnan, Bill Cook, Pierre Courrieu, Curtis Eaves, Kaoru Endo, Sharon Filipowski, Robert Freund, David Gay, Donald Hearn, T.C. Hu, Paparrizos Konstantinos, Siriphong Lawphongpanich, Jan Karel Lenstra, Janny Leung, A. Loshise, William Lucas, Charles McCallum, Jr., Masataka Nakamura, Michael Panik, Roman Polyak, Herbert Scarf, Alexander Schrijver, Bruce Shepherd, Richard Soland, Jie Sun, Roman Sznajder, Lakshman and Sarala Thakur, Michael Todd, Jean-Philippe Vial, Kevin Wayne, David Williamson, and H. Yamano.**



Online Algorithms: The State of the Art

Amos Fiat and Gerhard J. Woeginger (Eds.)

Lecture Notes in Computer Science, Vol. 1442, 1998

Springer Verlag

ISBN 3-540-64917-4

During the past years *online computation* has become an important field in mathematics, computer science and operations research. This is not only due to its intrinsic interest but also to its many applications.

Typically when one solves problems and designs algorithms one assumes that all the input data is known a priori. However, in many practical situations this assumption might not be true. Consider the following simple scenario: during a ski season an enthusiastic skier goes skiing every weekend that conditions permit. Since she does not own skis she asks herself whether to rent a pair or buy one. Clearly, if our skier knew a priori how long the season will last, then she could easily calculate her most inexpensive way through the season. Unfortunately, she does not have this complete knowledge but only discovers each weekend whether the season still continues or has already ended. Each time she is faced anew with the decision whether to rent or buy this time (unless she already bought some skies).

The area of online computation deals with the above outlined issue: an online algorithm must decide how to process incoming pieces of information without any knowledge of future ones. The online algorithm must make its decisions before the next bit of information is revealed and it is not allowed to revoke any of its past decisions. *Competitive analysis* has become the standard yardstick of how to judge online algorithms: the quality of an online algorithm is measured relative to the best possible performance of an (offline) algorithm that has complete knowledge of the future.

The book edited by Amos Fiat and Gerhard J. Woeginger addresses many aspects of online computation and competitive analysis. The chapters have been contributed by recognized experts in the field, and this has resulted in an excellent book about the current research in this area. Each chapter examines a specific application area and summarizes the related results in the literature.

The topics covered include classical online problems which initiated the research on competitive analysis such as self-organizing data structures or paging in virtual memory systems as well as more recent topics such as searching and navigation of unknown environments or online financial problems. The book also includes a good discussion on the applicability of competitive analysis in practice and its limitations.

The first chapter, written by the editors Amos Fiat and Gerhard J. Woeginger themselves, gives a brief introduction to competitive analysis and its history. Chapter 2 by Susanne Albers and Jefferey Westbrook surveys self-organizing data structures. Results and their proofs on organizing linear lists are complemented by an overview of splay trees and applications. In Chapter 3, Sandy Irani presents results about paging. This chapter also includes information about variants of competitive analysis such as loose competitiveness and access graphs.

Chapter 4 was written by Marek Chrobak and Lawrence L. Larmore. It gives an overview of metrical task systems and the famous *k*-server problem. This chapter contains many proofs, among them the celebrated theorem about the competitiveness of the "work-function algorithm" for the k-server problem. In Chapter5, Yair Bartal gives a nice survey of distributed paging. This area includes file migration and file allocation problems which have applications to distributed data bases and web-caching.

Chapter 6, written by James Aspnes, deals with the issue of combining competitive (sub-) algorithms in distributed systems to a globally competitive algorithm. Chapter 7 by János Csirik and Gerhard J. Woeginger covers online packing and covering problems. The bin-packing problem was one of the first problems to be studied from an online point of view. The authors discuss the bin-packing problem, its extensions to higher dimensions and geometric versions.

Chapter 8 by Yossi Azar is about online load balancing. This chapter is tightly connected to Chapter 11 on online network routing. The latter chapter was written by Stefano Leonardi and contains an enjoyable survey and some nice proofs. The also related area of scheduling is treated in great detail in Chapter 9 by Jirí Sgall.

The use of competitive analysis for online searching and navigation is discussed in Chapter 10 which was written by Piotr Berman. Chapter 12 by Bala Kalyanasundaram and Kirk Pruhs covers online network design problems. The authors also give pointers to online versions of the traveling salesperson problem. In Chapter13, Hal A.Kierstead surveys online graph-coloring problems. This chapter is an excellent source for results as well as applications of online graph coloring.

Chapter 14 was written by Avrim Blum and provides thorough information about online problems from Computational Learning Theory. The chapter also contains a nice list of open problems from this area. Online financial problems are the topic of Chapter 15 by Ran El-Yaniv. These problems have interesting applications in portfolio selection, search and leasing. In Chapter16, Anna Karlin comments on the performance of competitive algorithms in practice.

The last chapter is again written by the two editors, Amos Fiat and Gerhard J. Woeginger. In this chapter they indicate the limits of competitive analysis and comment on ways around some competitive odds and ends. Often "standard" competitive analysis fails to provide a theoretical explanation of behavior that is observed in practice. One such example is the fact that a number of paging algorithms (First-In-First-Out, Least-Recently-Used, etc.) all have the same competitive ratio k, where k equals the number of page slots in memory, but their performance in practice is quite different. Another problem with competitive analysis is that for some problems it only allows extremely weak positive results. The best possible competitive ratio is totally disappointing and is achieved by a trivial algorithm. An example is provided again by the paging problem: the First-In-First-Out page replacement strategy hits the "triviality barrier" of k.

In conclusion, Amos Fiat and Gerhard J. Woeginger as well as their guests have done an excellent job in producing a comprehensive survey of the most relevant results in online computation. There is one grain of salt that has to be added: The reader would probably like to see more proofs in the book (such as in Chapter 4 instance). However, due to the immense material covered in the book it was apparently not possible to include even more.

I strongly recommend the book edited by Amos Fiat and Gerhard J. Woeginger as a reference for researchers in the area of online computation. For readers new to the area, the reading should be supplemented by a study of a good textbook on online algorithms such as the recent book by Allan Borodin and Ran El-Yaniv [BEY98].

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References

[BEY98] A. Borodin and R. El-Yaniv, *Online computation and competitive analysis*, Cambridge University Press, 1998.

[FW98] A. Fiat and G. J. Woeginger (eds.), *Online algorithms: The state of the art*, Lecture Notes in Computer Science, vol. 1442, Springer, 1998.

Graphs, Networks and Algorithms

by Dieter Jugnickel

Springer Verlag, 1999

ISBN 3-540-63760-5

This book is the translation of a revised version of the third edition of the German text book 'Graphen, Netzwerke und Algorithmen' by Dieter Jungnickel. The first German edition appeared in 1987 and it was followed by other revised editions in 1990 and 1994. This is to say that the text has had the time to evolve and reach maturity and this English version is a well written and balanced textbook.

The chosen topics are in accordance with the title. As the author points out in the preface, "the present book concerns mainly that part of Combinatorial Optimization which can be formulated and treated by graph theoretical methods; neither the theory of Linear Programming nor Polyhedral Combinatorics are considered. Simultaneously, the book gives an introduction into Graph Theory." The list of chapter titles will better outline the scope of the book (the number of pages of each chapter is in parentheses): 1. Basic Graph Theory (34), 2. Algorithms and Complexity (28), 3. Shortest Paths (36), 4. Spanning Trees (30), 5. The Greedy Algorithm (26), 6. Flows (54), 7. Applications in Combinatorics (30), 8. Colourings (14), 9. Circulations (52), 10. Synthesis of Networks (26), 11. Connectivity (24), 12. Matchings (34), 13. Weighted Matchings (34), 14. A Hard Problem: the TSP (48). Then there is an appendix with the solutions of the exercises and an appendix with the list of symbols. In total the book comprises 590 pages. I would also say that sometimes the author is not able to stay within the self-inflicted bounds, as in Chapter 5, where matroids are presented as abstract combinatorial objects, or in Chapter 13 where he cannot refrain from introducing the matching polytope.

Given these data, it is not surprising that the topics are treated quite in depth and extensively. Indeed there is a wealth of material which could be suited for some advanced courses in graph or network theory. Ph.D. students could benefit a lot from the book. However, there is probably too much material for a typical Master's student. The book is a mathematical one. Definitions are carefully phrased (though not explicitly stated as such) and Theorems, Lemmas, and Corollaries go along with their proofs. Moreover, the text is interspersed with exercises which stimulate the reader to a more active understanding of the material. Figures are pervasive and quite welcome.

To convey a more detailed idea on the scope and depth of the book, here are some examples of topics which are rarely included in Graph Theory books and can be found in Jungnickel's book: path algebras in Chapter 3; the Matrix Tree Theorem (how to compute the number of spanning trees of a graph) and Steiner trees in Chapter 4; greedoids in Chapter 5; preflow ideas for maximal flows in Chapter 6; Cayley graphs in Chapter 7; edge coloring in Chapter 8, and so on. Clearly the basic material is always covered.

As a reference text this is a highly recommendable book to anyone working in this field. It is highly valuable and quite up-to-date. If you have to find a result together with its proof and background, then there is a good chance you will find it in this book. Of course this implies that it is not easy reading for the newcomer. In the preface the author says that this book has been used as a textbook in several universities and even at a special workshop for high school students. Well, I am full of admiration for the German students and their preparation if they can really go through these topics at ease. Personally I would recommend this book as a first course textbook to Mathematics (Master's) students (using the material to cover two semesters or even three semesters) and as an advanced (second course) textbook to Computer Science or Engineering students.

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Stochastic Linear Programming Algorithms: A comparison based on a model management system

János Meyer

Gordon and Breach Science Publishers, 1998

ISBN 90-5699-144-2

During the past decade there has been a lot of focus in the stochastic programming community on teaching the philosophy and tools of the field and several textbooks have appeared recently (see, e.g., the books by Birge & Louveaux [1], Kall & Wallace [2], and Prékopa [3]. This book by János Meyer focuses on a specific but important aspect of *stochastic linear programming* (SLP), namely algorithms for solving two-stage and chance-constrained SLP problems.

The book consists of six chapters discussing, respectively, general mathematical programming concepts, SLP models and algorithms, implementation and testing issues, and finally computational results.

The first part of the book is devoted to a survey of SLP models and algorithms. Chapter 1 begins by reviewing a number of results from convex and linear programming. Next, in Chapter 2, a number of SLP models are presented. The exposition is limited to two-stage and jointly chance-constrained models. On the one hand, this choice may seem restrictive and indeed rules out both interesting and relevant stochastic programming models, but these models are on the other hand very well studied and a number of solvers and algorithms are available for comparison. Finally, Chapter 3 reviews a number of SLP solution approaches with emphasis on decomposition and approximation/bounding results.

The second part of the book presents the implementation and testing environment used for carrying out computational experiments. Chapter 4 briefly describes the implementation and origin of the algorithms being tested. Many of these algorithms belong to the "classics" of stochastic programming, but implementations are, except for a few extensions, due to the author, and carried out in a testing environment which has been specifically developed to manage SLP problems. This model management system, which also has been described in numerous scientific articles by the book author and Peter Kall, is the topic of Chapter 5. The 6th and last chapter finally contains an extensive report on computational experiments using test problems from the literature as well as randomly generated and/or perturbed problems.

Overall, Meyer's book gives a well balanced introduction to stochastic linear programming algorithms with emphasis on computational topics. Although a revision of the author's Habilitationsschrift (postdoctoral degree) from the University of Zürich, the text is accessible to any person with some knowledge of mathematical (linear) programming, since the emphasis has been put on computational comparison. However, it is not an introductory stochastic programming textbook in the same sense as the previously mentioned books [1, 2, 3], since its scope is much too narrow in comparison. A possible limitation is also that the scope of the book is not development of new algorithms or solution methods, but rather a description and a comparison of already existing algorithms. This is also the strength of the book. Probably one of the most useful assets of the book is not actually a part of the book, but is the SLP-IOR model management system utilized for performing the computational experiments, manipulating model data and carrying out the testing. It should be mentioned that SLP-IOR is freely available for academic use from the authors. Thus this book/SLP-IOR may provide something which no textbook can do alone: giving hands-on modeling experience in classroom teaching.

In short, I find the book useful, both for readers already familiar with stochastic programming concepts – as it serves as a convenient (computational) documentation of algorithms and test problems which are otherwise scattered around in the scientific literature – and for newcomers and potential users of SLP techniques who are looking for descriptions of algorithms and their computational performance and characteristics and who do not wish to start right away reading journal articles.

–CLAUS C. CARØE, COPENHAGEN

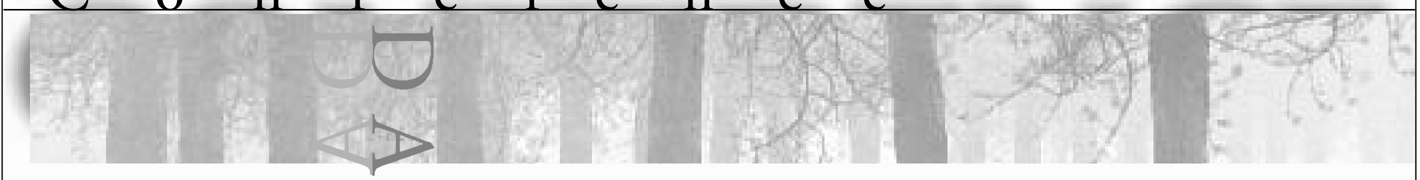
References

[1] J.R. Birge and F.V. Louveaux, Introduction to Stochastic Programming (Springer-Verlag, New York, 1997).

[2] P. Kall and S.W. Wallace, Stochastic Programming (Wiley-Interscience, New York, 1994).

[3] A. Prékopa, Stochastic Programming (Kluwer Academic Publishers, Dordrecht, 1995).

Conference Calendar



- **APMOD 2000**
  April 17-19, 2000,London,UK
  URL:http://www.apmod.org.uk
- **Seventh International Workshop on Project Management and Scheduling (PMS 2000)**
  April 17-19, 2000,University of Osnabrueck,Germany
  URL:http://www.mathematik.uni-osnabrueck.de/research/OR/pms2000/
- **Applied Mathematical Programming and Modelling Conference (APMOD 2000)**
  17-19 April 2000, Brunel University, London
  URL:http://www.apmod.org.uk
- **INFORMS Spring 2000**
  May 7-10, 2000, Salt Lake City, Utah,USA
  URL:http://www.informs.org/Conf/SaltLake2000/
- **STOC 2000**
  May 21-23, 2000, Portland,Oregon,USA
  URL:http://sigact.acm.org/stoc00
- **Tenth SIAM Conference on Discrete Mathematics**
  June 12-15, 2000,Minneapolis,Minnesota,USA
  URL:http://www.siam.org/meetings/dm00/
- **INFORMS/KORMS**
  June 18-21, 2000,Seoul, Korea
  URL:http://informs.scu.edu/seoul/
- **SIAM Annual Meeting**
  July 10-14, 2000, Rio Grande, Puerto Rico
  URL:http://www.siam.org/meetings/an00/
- **ISMP 2000 17th International Symposium on Mathematical Programming**
  August 7-11, 2000,Georgia Institute of Technology, Atlanta,GA,USA
  URL:http://www.isye.gatech.edu/ismp2000
- **First SIAM Conference on Computational Science and Engineering**
  September 21-23, Washington,DC,USA
  URL:http://www.siam.org/meetings/cse00/
- **INFORMS Fall 2000**
  November 3-7, 2000, San Antonio, Texas,USA
  URL:http://ie.tamu.edu/informs2000/
- **IPCO 2001**
  Utrecht, The Netherlands
  URL:http://www.cs.uu.nl/events/ipco2001/

First Announcement and Call for Papers

HPOPT 2000

5th International Conference on High Performance Optimization Techniques

Rotterdam, The Netherlands
June 7-9, 2000

HPOPT 2000 will take place in the context of the Dutch research project "High Performance Models for Mathematical Optimization." In this project, funded by the Dutch Organization for Scientific Research (NWO), research teams cooperate from four universities in the Netherlands: Delft University of Technology, Erasmus University, Eindhoven University of Technology, and University of Utrecht.

The aim of the conference is to bring together some of the most active researchers working on the design and implementation of optimization algorithms. We aim to cover the latest algorithmic developments, complexity results and implementation aspects, including the required tools from numerical algebra. Much attention will be given to the recent developments in semidefinite optimization and its relevance for a wide range of practical applications in fields such as combinatorial optimization, engineering design, matrix inequalities in systems and control theory, and matrix completion problems.

The meeting will consist of a one-day tutorial and a two-day conference. Along with invited presentations there will be sessions with contributed lectures.

Conference Organizers: Dick den Hertog (CQM, Eindhoven), Cor Hurkens (Eindhoven University of Technology), Jan Karel Lenstra (Eindhoven University of Technology/CWI), Leen Stougie (Eindhoven University of Technology), and Tjark Vredeveld (Eindhoven University of Technology).

Program Committee: Jan Brinkhuis (Erasmus University Rotterdam), Dick den Hertog (CQM, Eindhoven), Cor Hurkens (Eindhoven of University Technology), Jan Karel Lenstra (Eindhoven University of Technology/CWI), Kees Roos (Delft University of Technology), Leen Stougie (Eindhoven University of Technology), Henk van der Vorst (University of Utrecht), and Tjark Vredeveld (Eindhoven University of Technology).

Invited Speakers: Karen Aardal (University of Utrecht, The Netherlands), Aharon Ben–Tal (Technion, Haifa, Israel), N.G. de Bruijn (Eindhoven University of Technology, The Netherlands - to be confirmed), Martin Dyer (University of Leeds, Great Britain), Andrzej Ruszczynski (Rutgers University, New Brunswick, USA), Robert Vanderbei (Princeton University, USA), and Maarten van der Vlerk (University of Groningen, The Netherlands).

Submission of Papers: For contributed lectures, authors are kindly requested to submit a one-page abstract including title, author's name, affiliation, e-mail and postal address. Abstracts should be sent in LaTeX format to <hpopt@win.tue.nl>.

Registration: Pre-registration can be done through the web site or by sending an e-mail with your name and affiliation to <hpopt@win.tue.nl>. Upon pre-registration you will be kept up–to–date with any further announcements about the conference.

Registration can be done in the same way as pre-registration. Early registration is due on the 30th of April 2000. The conference fees for early registration are: For the one-day seminar on Wednesday, 7 June, Dgl 100; or the conference on 8 and 9 June, Dgl 200; For both, Dgl 300. For late registration, the fees for the two separate parts are augmented with Dgl 50 and for the three days with 100.

The conference fees include an abstract book, free lunches in the restaurant of the World Trade Center, coffee and tea with cookies during the breaks, a get–together on Wednesday evening and the conference dinner on Thursday evening. Upon cancellation before the 30th of April 2000, your conference fee will be refunded completely, up to bank costs. Upon cancellation before the 31st of May 2000, only half of your fee will be refunded. After that date no refunding is possible.

Important Dates: March 1, 2000 ***Deadline for abstracts***; March 31, 2000 ***Acceptance or rejection notification***; April 30, 2000 ***Deadline for early registration***; June 7-9, 2000 **HPOPT 2000**.

Information: Information about the conference can be found on the Conference Web Site: <http://www.win.tue.nl/~hpopt>. Further information can be obtained by sending an e–mail to: <hpopt@win.tue.nl>.

Call for Papers for Theme Issue of The Arabian Journal for Science and Engineering on Optimization Theory and Applications

The Editorial Board of the Arabian Journal for Science and Engineering (AJSE) plans to publish, in June 2000, a Theme Issue in Optimization Theory and Applications. The AJSE hopes to bring together in a single issue research papers that represent the state of the art in this vast and rapidly growing area.

The scope of this theme issue encompasses, but is not limited to, the following areas: linear programming; interior and exterior methods; quadratic programming; large scale optimization; stochastic programming; nonsmooth optimization; nonconvex programming; semidefinite programming; integer and combinatorial optimization; LCP; variational inequalities; heuristic-based optimization; and industrial applications.

Guest Editors Professor Katta G. Murty, Department of Industrial and Operations Engineering, University of Michigan; Professor Hanif D. Sherali, Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University.

Publication Schedule

Deadline for submission of manuscripts: January 10, 2000; Notification of acceptance of papers: March 31, 2000; Publication of the theme issue: June 2000.

Note to Authors: Four copies of the manuscript should be submitted to: Professor Harry Mavromatis, Managing Editor, The Arabian Journal for Science and Engineering, King Fahd University of Petroleum & Minerals KFUPM, Box 5033, Dhahran 31261, Saudi Arabia; Telephone: (+966) 3 8605418; Fax: (+966) 3 8605458; e-mail: <ajse@kfupm.edu.sa>.

Authors may obtain details of the format and style adopted by the AJSE by contacting the Managing Editor at the above address or by e-mail.

Call for Nominations: Optimization Prize for Young Researchers

Principal Guideline The Optimization Prize for Young Researchers, established in 1998 and administered by the Optimization Section (OS) within the Institute for Operations Research and Management Science (INFORMS), is awarded annually at the INFORMS Fall National Meeting to one (or more) young researchers for the most outstanding paper in optimization that is submitted to or published in a refereed professional journal. The prize serves as an esteemed recognition of promising colleagues who are at the beginning of their academic or industrial career.

Description of the Award The optimization award includes a cash amount of US$1,000 and a citation certificate. The award winners will be invited to give a one-hour lecture of the winning paper at the INFORMS Fall National Meeting in the year the award is made. It is expected that the winners will be responsible for the travel expenses to present the paper at the INFORMS meeting.

Eligibility The authors and paper must satisfy the following three conditions to be eligible for the prize:

(a) The paper must either be published in a refereed professional journal no more than three years before the closing date of nomination, or be submitted to and received by a refereed professional journal no more than three years before the closing date of nomination;

(b) All authors must have been awarded their terminal degree within five years of the closing date of nomination;

(c) The topic of the paper must belong to the field of optimization in its broadest sense.

Nomination Nominations should be sent before July 15, 2000 to

Robert J. Vanderbei
Dept. of Operations Research and Financial Engineering
Princeton University
Princeton, NJ 08544

Nominations should be accompanied by a supporting letter.

Second Announcement

Seventh DIMACS Implementation Challenge

Semidefinite and Related Optimization Problems

The workshop of the Seventh DIMACS Challenge has been postponed to September 13–15, 2000. We have received many excellent proposals (see the web site address below), but also a fair number of requests to allow more time for projects which were otherwise unlikely to finish before January. New proposals are still welcome.

For up-to-date information on the workshop, please see the Challenge web site at <http://dimacs.rutgers.edu/Challenges>. For the collection of test problems, visit <http://dimacs.rutgers.edu/Challenges/Seventh/Instances/>.

–FARID ALIZADEH, DAVID JOHNSON, GABOR PATAKI

NEOS

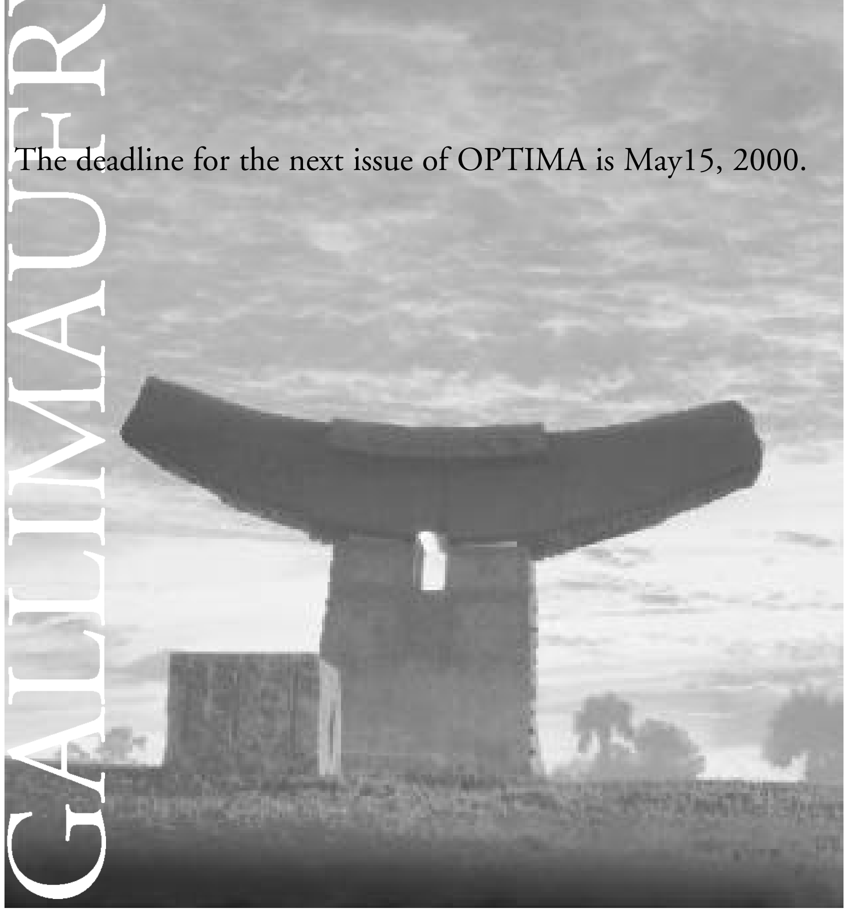
Version 2 of the NEOS Server was de-commissioned on March 4, 1999, after having processed 39,900 submissions. Version 3 of the NEOS Server (NEOS 99) went into operation the same day, and is continually being improved. The new server can be found at <http://neos.mcs.anl.gov/>.

NEOS 99 is a major improvement. This version is portable, faster, more reliable, allows submissions from the local file space, and accepts compressed data. We have also added a considerable number of new solvers. In particular, for integer programming: MINLP (Roger Fletcher and Sven Leyffer), XPRESS-MP/INTEGER (Dash Associates and Dash Optimization); for complementarity problems: MILES (GAMS Development Corporation and T. Rutherford), PATH (GAMS Development Corporation and S. Dirkse, M. Ferris and T. Munson); for nonlinearly constrained optimization: DONLP2 (Hans Mittelmann and Peter Spellucci), FILTER (Roger Fletcher and Sven Leyffer), LANCELOT (Andy Conn, Nick Gould and Philippe Toint), LOQO (Robert Vanderbei), MINOS (Bruce Murtagh and Michael Saunders), SNOPT (Philip Gill, Walter Murray and Michael Saunders); for bound-constrained optimization: L-BFGS-B (Ciyou Zhu, Richard Byrd, Peihuang Lu, and Jorge Nocedal), TRON (Chih-Jen Lin and Jorge Moré); and for positive semidefinite programming: DSDP (Steve Benson, Yinyu Ye, and Xiong Zhang). Many of the solvers accept input in AMPL format, and we have recently added solvers that accept input in GAMS format.

We welcome comments and suggestions. In particular, we are seeking comments from NEOS users who support our continuing effort to offer this service to the public. The easiest way to provide user feedback is by sending e-mail to <neos-comments@mcs.anl.gov>.

–LIZ DOLAN AND JORGE MORÉ FOR THE NEOS GROUP

GALLIMAUFRY



The deadline for the next issue of OPTIMA is May15, 2000.

Touch the Sky, a sculpture by Robert Sindorf, on the campus of the University of Florida

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