

2

AD-A250 811



Dr. Harvey J. Greenberg
Mathematics Department, Campus Box 170
University of Colorado at Denver
P.O. Box 173364
Denver, CO 80217-3364
303-556-8464
BITNET: hgreenberg@cudenver
FAX: 303-556-3377

SDTIC
ELECTE
MAY 19 1992
A D

October 28, 1991

Dr. Donald K. Wagner, Scientific Officer
Mathematical Sciences Division
Office of the Chief of Naval Research
800 N. Quincy Street
Arlington, VA 22217-5000

RE: Contract #N00014-88-K-0104

Dear Dr. Wagner:

Our research administration office received a request for a final report on our project, *The Development of Modularized Software for Empirical Testing of New Algorithms in Linear Programming*. The project was originally for a three year period from Oct. 1, 1987-September 30, 1990. Although from a scientific point of view, our work was mostly concluded a year ago, we requested and received a one-year no cost extension to permit us to complete publications, travel to professional meetings and make presentations of our research results. An updated list of technical reports, publications and presentations is enclosed. This constitutes our final report.

A summary of the work accomplished follows.

Empirical research into new strategies and tactics for linear programming requires realistic, large-scale problem-solving tools. The Workbench for Research In (linear) Programming, called WRIP, is a highly modularized system for generating, solving and analyzing instances of linear programs. The core of WRIP is OB1, an advanced optimizer that includes simplex and interior point methods. To support basic operations, OB1 contains a linear algebra library and related routines to process large, sparse matrices. Its modular structure enables algorithm experimentation by modifying one or more of its subroutines. In order to test ideas and gain insight into

This document has been approved for public release and sale; its distribution is unlimited.

92-11841



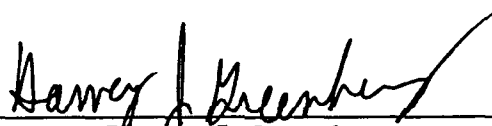
92 4 29 103

an algorithm's performance, WRIP includes a modeling language, called MODLER, and a controlled randomization module, called RANDMOD. These enable meaningful randomization on raw data elements and matrix operations, respectively, that preserve the realism of the structure of the linear programming model while applying statistical inference. In addition, an interactive analysis system, called ANALYZE, is included to gain insights into problem and solution properties for deeper analysis of results. All modules are written in Fortran/77 and have been tested in a variety of computing environments.

WRIP has been distributed to about 30 academics engaged in mathematical programming research, in the U.S. and Europe. In addition, the principal investigators have extended their own insights into algorithm design through experimental rigor made possible by this software.

Please let me know if more information is required.

Sincerely,



Harvey J. Greenberg
Professor, and Principal Investigator

HJG/tmc

- Encl. Report documentation page
List of publications, technical reports and presentations
Distribution list for WRIP
ANALYZE primer + disk
MODLER primer + disk
RANDMOD primer + disk

cc: Vickie Spencer, CU-Denver Research Administration
Roy Marsten, Co-PI, Georgia Tech

Accession For	
NTIS	CRA&I
DTIC	TAB
Unannounced	
Justification	
By _____	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

Statement A per telecon
Dr. Donald Wagner ONR/Code 1111
Arlington, VA 22217-5000

NWW 5/18/92



REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE Oct. 31, 1991	3. REPORT TYPE AND DATES COVERED Final 10/1/87-9/30/91
----------------------------------	--	--

4. TITLE AND SUBTITLE The Development of Modularized Software for Empirical Testing of New Algorithms in Linear Programming	5. FUNDING NUMBERS Contract # N00014-88K-0104
---	---

6. AUTHOR(S) Harvey J. Greenberg	
--	--

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Colorado at Denver P.O. Box 173364 Denver, CO 80217-3364	8. REPORT NUMBER
---	------------------

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research Mathematical Sciences Division 800 N. Quincy Arlington, VA 22217-5000	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
--	--

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT Entire contents available to the public	12b. DISTRIBUTION CODE
--	------------------------

13. ABSTRACT (Maximum 200 words)

Empirical research into new strategies and tactics for linear programming requires realistic, large-scale problem-solving tools. The Workbench for Research In (linear) Programming, called WRIP, is a highly modularized system for generating, solving and analyzing instances of linear programs. The core of WRIP is OB1, an advanced optimizer that includes simplex and interior point methods. To support basic operations, OB1 contains a linear algebra library and related routines to process large, sparse matrices. Its modular structure enables algorithm experimentation by modifying one or more of its subroutines. In order to test ideas and gain insight into an algorithm's performance, WRIP includes a modeling language, called MODLER, and a controlled randomization module, called RANDMOD. These enable meaningful randomization on raw data elements and matrix operations, respectively, that preserve the realism of the structure of the linear programming model while applying statistical inference. In addition, an interactive analysis system, called ANALYZE, is included to gain insights into problem and solution properties for deeper analysis of results. All modules are written in FORTRAN/77 and have been tested in a variety of computing environments.

WRIP has been distributed to about 30 academics engaged in mathematical programming research, in the U.S. and Europe. In addition, the principal investigators have extended their own insights into algorithm design through experimental rigor made possible by this software.

14. SUBJECT TERMS

linear programming, computational experimentation, interior point methods, sparse linear algebra

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified
--	---	--

PUBLICATIONS TECHNICAL REPORTS AND PRESENTATIONS

(cumulative)

sponsored by ONR contract N00014-88-K-0104

October 1987-September 30, 1991

Publications and Technical Reports:

E. Gelman, and J. Mandel, 1989. On Multilevel Iterative Methods for Optimization Problems, *Mathematical Programming Studies*, 48:1, 1-18.

R. E. Marsten, 1989. User's Manual for: OB1/XMP, Interior Point Methods for Linear Programming.

R. E. Marsten, M. J. Saltzman, D. F. Shanno, G. S. Pierce, and J. F. Ballintijn, 1989. Implementation of a Dual Affine Interior Point Algorithm for Linear Programming, *ORSA Journal on Computing* 1:4, pp. 287-297.

M. J. Saltzman, R. Subramanian, and R. E. Marsten, 1989. Implementing an Interior Point LP Algorithm on a Supercomputer, in *Proceedings of CSTS Symposium, Impacts of Recent Computer Advances on Operations Research*, R. Sharda, B.L. Golden, E. Wasil, O. Balci, and W. Stewart (eds.), North-Holland, pp. 158-168.

H. J. Greenberg, and R. E. Marsten, 1990. WRIP: Workbench for Research In (linear) Programming, Version 1.0.

H.J. Greenberg, 1990. *ANALYZE User Documentation*. Mathematics Department, University of Colorado at Denver, Denver, CO.

H.J. Greenberg, 1990. *MODLER User Documentation*. Mathematics Department, University of Colorado at Denver.

H.J. Greenberg, 1990. *RANMOD User Documentation*. Mathematics Department, University of Colorado at Denver, Denver, CO.

H. J. Greenberg, 1990. Computational Testing: Why, How and How Much, *ORSA Journal on Computing* 2:1, 94-97.

R.E. Marsten, 1990. *OB1 User Documentation*. Department of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, GA.

- R. E. Marsten and R. Subramanian, 1990. Interior Point Methods for Linear Programming: Just Call Newton, laGrange, and Fiacco & McCormick!, *Interfaces* 20:4, 105-116.
- R. E. Marsten, I. Lustig, and D. Shanno, 1990. The Primal-Dual Point Method on the Cray Supercomputer, *Large Scale Numerical Optimization*, Thomas F. Coleman ed., SIAM, Philadelphia, PA.
- R. E. Marsten, I. Lustig, and D. Shanno, 1990. On Implementing Mehrotra's Predictor-Corrector Interior Point Method for Linear Programming (submitted to *SIAM Journal on Optimization*).
- H. J. Greenberg, 1991. RANDMOD: A System for Randomizing Modifications to an Instance of a Linear Program, *ORSA Journal on Computing* 3:2, 173-175.
- H.J. Greenberg, 1991. Enhancements of ANALYZE: A Computer-Assisted Analysis System for Mathematical Programming Models and Solutions, submitted to *ACM TOMS*.
- H.J. Greenberg, 1991. An Empirical Analysis of Diagnosing Infeasible Instances of Linear Programming Blending Models, to appear in *IMA Journal on Mathematics in Business*.
- H.J. Greenberg, 1991. MODLER: Modeling by Object-Driven Linear Elemental Relations, to appear in *Annals of OR*.
- H.J. Greenberg, 1991. *A Primer for RANDMOD: A System for Randomizing Modifications to an Instance of a Linear Program*, book submitted to Kluwer.
- H.J. Greenberg, *A Primer for MODLER: Modeling by Object-Driven Linear Elemental Relations*, book submitted to Kluwer.
- H.J. Greenberg, *A Primer for ANALYZE: A Computer-Assisted Analysis System for Mathematical Programming Models and Solutions*, book submitted to Kluwer.
- I.J. Lustig, R.E. Marsten, D.F. Shanno, 1991. Computational Experience with a Primal-Dual Interior Point Method for Linear Programming, *Linear Algebra and Applications*, 152, 1991. 191-222.
- R. E. Marsten, I. Lustig, and D. Shanno, 1991. The Interaction of Algorithms and Architectures for Interior Point Methods, to appear in *Advances in Optimization and Parallel Computing*, Panos Pardalos, ed., North Holland.

R. E. Marsten, I. Lustig, and D. Shanno, 1991. Starting and Restarting the Primal-Dual Interior Point Method, submitted to *OR Letters*.

R. E. Marsten, H. Jung, and M. Saltzman, 1991. The Column Cholesky Method for Numerical Factorization in Interior Point Algorithms, submitted to *ORSA Journal on Computing*.

R. E. Marsten, R. Bixby, W. Gregory, I. Lustig, and D. Shanno, 1991. Very Large-Scale Linear Programming: A Case Study in Combining Interior Point and Simplex Methods, submitted to *Operations Research*.

Presentations:

R. E. Marsten, 1988. A Dual Affine Interior Point Algorithm for LP's With Bounded Variables. ORSA/TIMS Joint National Meeting, Denver, Colorado, Oct. 23-26, 1988.

R. E. Marsten, D. Shanno, and M. Saltzman, 1989. Further Algorithmic Development for the Dual Affine and the Dual Barrier Interior Methods. The Third SIAM Conference on Optimization, Boston, April 3-5, 1989.

H. J. Greenberg, 1989. A Model Assistant for Linear Programming. CORS/TIMS/ORSA Joint National Meeting, Vancouver, Canada, May 8-10, 1989.

R. E. Marsten, 1989. The Dual Affine Interior Point Method for Linear Programming Implementation on Cray Supercomputers. CORS/TIMS/ORSA Joint National Meeting, Vancouver, Canada, May 8-10, 1989.

R. E. Marsten and D. Shanno, 1989. Interior Point Method for Linear Programming: Ready for Production. ORSA Practitioner Workshop, ORSA/TIMS Joint National Meeting, October 15-17, 1989.

R. E. Marsten and D. Shanno, 1989. Set Partition Via Interior Point Method. ORSA/TIMS Joint National Meeting, October 15-17, 1989.

R. E. Marsten, D. Shanno, and M. Saltzman, 1989. Solving Set Partitioning Problems with Cutting Planes and an Interior Point Method. ORSA/TIMS Joint National Meeting, New York, October 15-17, 1989.

R. E. Marsten, 1990. Computational Experience with a Primal/Dual Interior Point Method for Linear Programming. ORSA/TIMS Joint National Meeting, Las Vegas, NV, May 7-9, 1990.

- R. E. Marsten, 1990. WRIP: A Workbench for Research in Interior Point Methods. ORSA/TIMS Joint National Meeting, Philadelphia, PA, October 29-31, 1990.
- R. E. Marsten, 1990. Recent Computational Experience with a Primal Dual Interior Point Method for Linear Programming. ORSA/TIMS Joint National Meeting, Philadelphia, PA, October 29-31, 1990.
- R. E. Marsten, 1991. Architecture, Algorithms, and Efficiency of Interior Point Methods for Linear Programming. ORSA/TIMS Joint National Meeting, Nashville, TN, May 12-15, 1991.
- R. E. Marsten, 1991. Recent Advances in the OB1 Interior Point Code. ORSA/TIMS Joint National Meeting, Nashville, TN, May 12-15, 1991.
- R. E. Marsten, 1991. Continuing Interior Point and Simplex Methods for LP. 14th International Symposium on Mathematical Programming, Amsterdam, The Netherlands, August 5-9, 1991.

Dr. Ilan Adler
IE & OR Department
University of California-Berkeley
Berkeley, CA 94720

Dr. Fernando A. Alvarado
Department of Electrical and
Computer Engineering
University of Wisconsin
1415 Johnson Drive
Madison, WI 53706-1691

Professor Dr. A. Bachem
Mathematisches Institute der
Universitaet zu Köln
Weyertal 86-90
D-5000 Köln 41
FEDERAL REPUBLIC OF
GERMANY

Dr M.P. Biswal
Department of Mathematics
Indian Insitute of Technology
Khaagipur - 721302
INDIA

Dr. Jürgen Bruchhaus
Universität zu Köln
Mathematisches Institut
Weyertal 86-90
5000 Köln 41
FEDERAL REPUBLIC OF
GERMANY

Dr. John W. Chinneck
Systems & Computer Engineering
Carleton University
Ottawa, Ontario
CANADA K1S 5B6

Dr. David Chudnovsky
Department of Mathematics
Room 610 Mudd Building
Columbia University
New York, NY 10027

Dr. M.A.H. Dempster
Computer Science Department
Dalhousie University
Halifax, Nova Scotia B3H4H8
CANADA

Dr. R.M. Dunnett
The National Grid Research and
Development Centre
Kelvin Avenue
Leatherhead, Surrey KT22 7ST
UNITED KINGDOM

Dr. Joe Ecker
ITS
322 VCC
RPI
Troy, NY 12180-3590

Dr. Gerald Evans
Department of Industrial Engineering
University of Louisville
Louisville, KY 40292

Dr. Gus Gassman
School of Business Administration
Dalhousie University
Halifax, Nova Scotia B3H 4H8
CANADA

Dr. Donald Goldfarb
IEOR Department
Columbia University
New York, NY 10027

Dr. Elsie Gottlieb
Department of Statistics/CIS
Baruch College
The City University of New York
17 Lexington Avenue
New York, NY 10010

Dr. Tony Hürlimann
Institute for Automation & OR
University Misericorde
CH-1700 Fribourg
SWITZERLAND

Mr. Dick Jacobson
NDHECN
NDSU Computer Center
Box 5164
Fargo, ND 58105

Dr. Michael Jünger
Naturwissenschaftliche Fakultät
Universität Augsburg
Memminger Str. 6
D-8900 Augsburg
FEDERAL REPUBLIC OF
GERMANY

Dr. Masakazu Kojima
Department of Information Sciences
Tokyo Institute of Technology
O-okayama, Meguro-ku
Tokyo 152
JAPAN

Dr. Weldon Lodwick
Mathematics Department
University of Colorado at Denver
1200 Larimer Street
Denver, CO 80204

Dr. Oli G. Madsen
The Institute of Mathematical
Statistics and
Operations Research
Building 321
The Technical University of Denmark
DK-2800 Lyngby
DENMARK

Dr. Istvan Maros
Computer and Automation Institute
Hungarian Academy of Sciences
P.o. Box 63 XI. Kende U. 13-17
H-1518 Budapest
HUNGARY

Dr. Robert Meyer
Computer Sciences Department
University of Wisconsin-Madison
Madison, WI 53706

Dr. Gautam Mitra
Department of Mathematics &
Statistics
Brunel University
Uxbridge, Middlesex UB8 3PH
UNITED KINGDOM

Dr. Frederic H. Murphy
Department of Management
Business School
Temple University
Philadelphia, PA 19122

Dr. Charles Mylander
Mathematical Sciences Division
Office of Chief of Naval Research
800 N. Quincy
Arlington, VA 22217-5000

Dr. Ken McAloon
Department of Computer &
Information Science
Brooklyn College
The City University of New York
Brooklyn, NY 11210

Dr. W.F. Mc Coll
Program Research Group
Oxford University
11 Keble Road
Oxford OX1 3QD
UNITED KINGDOM

Dr. Jeffrey L. Popyack
Department of Mathematics and
Computer Science
Drexel University
Philadelphia, PA 19104

Dr. Francisco J. Prieto
Dept. de Automatica, Electronica e
Informatica Industrial
E.T.S. Ingenieros Industriales
Jose Gutierrez Abascal, 2
E-28006 Madrid
SPAIN

Dr. L.G. Proll
School of Computer Studies
The University of Leeds
Leeds LS2 9JT
UNITED KINGDOM

Dr. Matthew Saltzman
Department of Mathematical Sciences
Clemson University
Clemson, SC 29631

Dr. Michael Saunders
Department of Operations Research
Stanford University
Stanford, CA 94305-4022

Dr. David Shanno
RUTCOR Hill Center
Rutgers University
New Brunswick, NJ 08903

Dr. John Tomlin
IBM Almaden Research Center
650 Harry Road, K53/802
San Jose, CA 95120

Dr. Kaoru Tone
Graduate School of Policy Sciences
Saitama University
Urawa, Saitama 338
JAPAN

Dr. Wilbert E. Wilhelm
Department of Industrial Engineering
College of Engineering
Texas A & M University
College Station, TX 77843

Dr. W.P. Willers
School of Computing & Mathematics
Teesside Polytechnic
Middlesbrough
Cleveland, TS1 3BA
UNITED KINGDOM

Dr. Steve Wright
Mathematics Department, Box 8205
North Carolina State University
Raleigh, NC 27695-08205

Dr. Hossam Zaki
140 MEB
University of Illinois, Urbana-
Champaign
1206 W. Green Street
Urbana, IL 61801

Prof. Dr. U. Zimmermann
Institut für Angewandte Mathematik
Abteilung Mathematische
Optimierung
Technische Universität
Braunschweig
Pockelsstr. 14
D-3300 Braunschweig
FEDERAL REPUBLIC OF
GERMANY"