Mathematics of Computation



EDITED BY James H. Bramble, Managing Editor Carl de Boor **Todd Dupont** Walter Gautschi **Donald Goldfarb Eugene** Isaacson Heinz-Otto Kreiss Yudell L. Luke James N. Lyness Morris Newman John E. Osborn **Beresford Parlett** Philip Rabinowitz John R. Rice **Daniel Shanks** Charles C. Sims Hans J. Stetter Vidar C. Thomée Hugh C. Williams John W. Wrench, Jr.

July 1981

Volume 37, Number 155, Pages 1-242

Published by the American Mathematical Society Providence, Rhode Island USA ISSN 0025-5718

Editorial Committee

JAMES H. BRAMBLE, Chairman. Dept. of Mathematics, White Hall, Cornell Univ., Ithaca, NY 14853 CARL DE BOOR, Mathematics Research Center, Univ. of Wisconsin, Madison, WI 53706 MORRIS NEWMAN, Dept. of Mathematics, Univ. of California, Santa Barbara, CA 93106 DANIEL SHANKS, Dept. of Mathematics, Univ. of Maryland, College Park, MD 20742

Technical Editor

ANITA WAHLBIN, Dept. of Mathematics, White Hall, Cornell Univ., Ithaca, NY 14853

Board of Associate Editors

TODD DUPONT, Dept. of Mathematics, Univ. of Chicago, Chicago, IL 69637

WALTER GAUTSCI I, Computer Sciences Dept., Purdue Univ., West Lafayette, IN 47907

DONALD GOLDFARB, Dept. of Computer Sciences, School of Engineering, The City College of the City Univ. of New York, 139th Street & Convent Avenue, New York, NY 10031

EUGENE ISAACSON, Courant Institute of Mathematical Sciences, New York Univ., 251 Mercer Street, New York, NY 10012

HEINZ-OTTO KREISS, Dept. of Applied Mathematics, California Inst. of Technology, Pasadena, CA 91125

YUDELL L. LUKE, Dept. of Mathematics, Univ. of Missouri at Kansas City, Kansas City, MO 64110

JAMES N. LYNESS, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439

JOHN E. OSBORN, Dept. of Mathematics, Univ. of Maryland, College Park, MD 20742

BERESFORD PARLETT, Dept. of Computer Science, Univ. of California, Berkeley, CA 94720

PHILIP RABINOWITZ, Dept. of Applied Mathematics, The Weizmann Institute of Science, Rehovot, Israel

JOHN R. RICE, Division of Mathematical Sciences, Purdue Univ., Lafayette, IN 47907

CHARLES C. SIMS, Dept. of Mathematics, Rutgers Univ., New Brunswick, NJ 08903

HANS J. STETTER, Institut für Numerische Mathematik, Technische Universität Wien, Karlsplatz 13, A-1040, Wien, Austria

VIDAR C. THOMEE, Mathematics Dept., Chalmers Univ. of Technology, Göteborg, Sweden

HUGH C. WILLIAMS, Dept. of Computer Science, Univ. of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

JOHN W. WRENCH, JR., 6310 Jefferson Blvd., Frederick, MD 21701

SUBSCRIPTION INFORMATION: MATHEMATICS OF COMPUTATION is published quarterly, with issues numbered serially since Volume 1, Number 1. Subscription prices for Volumes 36 and 37 (1981) are \$65.00 list; \$45.00 institutional member; \$35.00 member of CBMS organizations; \$25.00 individual AMS member. Combination paper and microform (microfiche or microfilm) subscription prices are \$87.00 list; \$60.00 institutional member; \$47.00 member of CBMS organizations; \$33.00 individual AMS member. Microfiche of each issue will be mailed the fastest way before the camera copy is sent to the printer.

BACK NUMBER INFORMATION: Back number prices *per volume* are for Volumes 1–27, \$36.00 list, \$27.00 member; for Volumes 28–29, \$54.00 list, \$40.50 member; for Volume 30, \$72.00 list, \$54.00 member; for Volumes 31–33, \$84.00 list, \$63.00 member; for Volumes 34–35, \$49.00 list, \$36.75 member. Beginning with Volume 32, back volumes are also available on 16mm positive or negative microfilm or on microfiche; Volumes 1–31 are available on microfilm only, not microfiche. The microfilm may be mounted on spools or in Kodak or 3M cartridges. Only current subscribers are eligible to purchase back volumes on microform. Write to the AMS for a detailed price list.

UNPUBLISHED MATHEMATICAL TABLES: The editorial office of the journal maintains a repository of Unpublished Mathematical Tables (UMT). When a table is deposited in the UMT repository a brief summary of its contents is published in the section *Reviews and Descriptions of Tables and Books*. Upon request, the chairman of the editorial committee will supply copies of any table for a nominal cost per page. All tables and correspondence concerning the UMT should be sent to James H. Bramble, Chairman, Department of Mathematics, White Hall, Cornell University, Ithaca, NY 14853.

Orders for subscriptions and publications of the American Mathematical Society should be addressed to the AMS, P. O. Box 1571, Annex Station, Providence, R.I. 02901. All orders must be accompanied by payment. Other correspondence should be addressed to P. O. Box 6248, Providence, R.I. 02940.

MATHEMATICS OF COMPUTATION is published quarterly by the American Mathematical Society, 201 Charles Street, Providence, RI 02904. Second-class postage is paid at Providence, Rhode Island, and additional mailing offices. Postmaster: Send address changes to Mathematics of Computation, American Mathematical Society, P. O. Box 6248, Providence, RI 02940.

Mathematics of Computation

EDITED BY

James H. Bramble, Managing Editor Carl de Boor **Todd Dupont** Walter Gautschi **Donald Goldfarb** Eugene Isaacson Heinz-Otto Kreiss Yudell L. Luke James N. Lyness Morris Newman John E. Osborn **Beresford Parlett** Philip Rabinowitz John R. Rice **Daniel Shanks** Charles C. Sims Hans J. Stetter Vidar C. Thomée Hugh C. Williams John W. Wrench, Jr.

VOLUME 37 · 1981 · NUMBERS 155-156

Providence, Rhode Island, USA ISSN 0025-5718

Information for Contributors

Manuscripts should be typewritten double-spaced in the format used by the journal. For journal abbreviations, see the latest *Mathematical Reviews* volume index. An author should submit the original and two copies of the manuscript and retain one copy. The author may suggest an appropriate editor for his paper. It is recommended that the author acquaint himself with the pertinent material contained in "A Manual for Authors of Mathematical Papers," which is available from the American Mathematical Society. All contributions intended for publication and all books for review should be addressed to James H. Bramble, Chairman, Editorial Committee, Mathematics of Computation, Department of Mathematics, White Hall, Cornell University, Ithaca, New York 14853. Institutions sponsoring research reported in the journal are assessed page and microfiche charges.

Each article submitted for publication must be accompanied by a brief and reasonably self-contained abstract, and by 1980 *Mathematics Subject Classification* numbers. If a list of key words and phrases is included, it will be printed as a footnote on the first page. A list of the classification numbers may be found in the 1978 Subject Index to Mathematical Reviews.

The research journals of the American Mathematical Society carry a page charge of \$40.00 per page to help defray the cost of publication. This amount is charged to the institution or to a contract supporting the research reported in the published paper. The publication charge policy of the United State Federal Council for Science and Technology (FCST) is reported on page 112 of the February, 1975 issue of the NOTICES of the American Mathematical Society. In no case is the author personally responsible for paying the page charge, nor is acceptance of the author's paper for publication dependent upon payment of the page charge.

Copying and Reprinting

Individual readers of this publication, and nonprofit libraries acting for them are permitted to make fair use of the material, such as to copy an article for use in teaching or research. Permission is granted to quote brief passages from this publication in reviews provided the customary acknowledgement of the source is given.

Republication, systematic copying, or multiple reproduction of any material in this publication (including abstracts) is permitted only under license from the American Mathematical Society. Requests for such permission should be addressed to the Executive Director, American Mathematical Society, Box 6248, Providence, Rhode Island 02940.

The appearance of the code on the first page of an article in this journal indicates the copyright owner's consent for copying beyond that permitted by Sections 107 or 108 of the U. S. Copyright Law, provided that the copier pay the stated per copy fee through the Copyright Clearance Center, Inc., 21 Congress Street, Salem, Massachusetts 01970. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotion purposes, for creating new collective works, or for resale.

MATHEMATICS OF COMPUTATION TABLE OF CONTENTS

July 1981

James H. Bramble, The Lagrange Multiplier Method for Dirichlet's Problem	1
Juhani Pitkäranta, The Finite Element Method With Lagrange Multipliers for Do-	-
mains With Corners	13
M. Vogelius and I. Babuška, On a Dimensional Reduction Method. I. The Opti- mal Selection of Basis Functions	31
M. Vogelius and I. Babuška, On a Dimensional Reduction Method. II. Some Approximation-Theoretic Results	47
D. L. Hicks, Hydrocode Subcycling Stability	69
Alan E. Berger, Jav M. Solomon and Melvyn Ciment. An Analysis of a Uniformly	
Accurate Difference Method for a Singular Perturbation Problem	79
Athena Makroglou, A Block-by-Block Method for Volterra Integro-Differential Equations With Weakly-Singular Kernel	95
M. Madalena Martins, Note on Irreducible Diagonally Dominant Matrices and the Convergence of the AOR Iterative Method	101
Y. Saad, Krylov Subspace Methods for Solving Large Unsymmetric Linear Systems.	105
James A. Pennline, Improving Convergence Rate in the Method of Successive Approximations	127
C. B. Dunham and Jack Williams, Rate of Convergence of Discretization in	105
Chebyshev Approximation	135
P. Lancaster and K. Salkauskas, Surfaces Generated by Moving Least Squares Methods	141
J. Marshall Ash and Roger L. Jones, Optimal Numerical Differentiation Using Three Function Evaluations	159
Bing-Yuan Ting and Yudell L. Luke, Computation of Integrals With Oscillatory and Singular Integrands	169
B. Mond , On Algorithmic Equivalence in Linear Fractional Programming	185
John P. Boyd, The Rate of Convergence of Chebyshev Polynomials for Functions Which Have Asymptotic Power Series About One Endpoint	189
J. P. Delahave. Automatic Selection of Sequence Transformations	197
C. J. Smyth. On the Measure of Totally Real Algebraic Integers. II	205
Rudolf A. Mathon, Kevin T. Phelps and Alexander Rosa, A Class of Steiner Triple Systems of Order 21 and Associated Kirkman Systems	209
A. J. W. Duijvestijn and P. Leeuw, Lowest Order Squared Rectangles and Squares	
With the Largest Element Not on the Boundary	223
Robert Baillie, G. Cormack and H. C. Williams, The Problem of Sierpiński Concern-	
$\inf k \cdot 2^n + 1$	229

Arne Fransén, Addendum and Corrigendum to "High-Precision Values of the	
Gamma Function and of Some Related Coefficients"	233
Reviews and Descriptions of Tables and Books	237
Shampine and Gordon 12, Brezinski 13, Kennedy and Gentle 14	

SEQUENCE TRANSFORMATIONS AND THEIR APPLICATIONS



BY JET WIMP

A VOLUME IN THE MATHEMATICS IN SCIENCE AND ENGINEERING SERIES

CHAPTER HEADINGS: Sequences and Series. Linear Transformations. Linear Lozenge Methods. Optimal Methods and Methods Based on Power Series. Nonlinear Lozenges: Iteration Sequences. The Schmidt Transformation: The ϵ -Algorithm. Aitken's δ^2 -Process and Related Methods. Lozenge Algorithms and the Theory of Continued Fractions. Other Lozenge Algorithms and Nonlinear Methods. The Brezinski-Håvie Protocol. The Brezinski-Håvie Protocol and Numerical Quadrature. Probabilistic Methods. Multiple Sequences. Appendix. Index.

1981, 288 pp., \$38.50 ISBN: 0-12-757940-0

ANALYSIS AND COMPUTATION OF FIXED POINTS

EDITED BY STEPHEN M. ROBINSON

The papers published in this book arose primarily from the Symposium on Analysis and Computation of Fixed Points, held at the University of Wisconsin, Madison on May 7 and 8, 1979. CONTENTS: *M. J. Todd*, Numerical Stability and Sparsity in Piecewise-Linear Algorithms. *S. Shamir*, Two New Triangulations for Homotopy Fixed Point Algorithms with an Arbitrary Grid Refinement. *D. G. Saari and R. Saigal*, Some Generic Properties of Paths Generated by Fixed Point Algorithms. *T.-Y. Li and J. A. Yorke*, A Simple Reliable Numerical Algorithm

INTERVAL MATHEMATICS 1980

EDITED BY KARL L. E. NICKEL

Proceedings of an International Symposium on Interval Mathematics held in Freiburg i. Br./Germany from May 27 to 31, 1980.

INVITED LECTURES: N. Apostolatos and G. Karabatzos, Set Functions and Applications. E. R. Hansen and S. Sengupta, Global Constrained Optimization Using Interval Analysis. P. Henrici, A Model for the Propagation of Rounding Error in Floating Arithmetic. K.-U. Jahn, The Importance of 3-Valued Notions for Interval Mathematics. W. M. Kahan, Interval Arithmetic Options in the Proposed IEEE Floating

Future volumes in the MATHEMATICS IN SCIENCE AND ENGINEERING Series are now available on a Continuation Order basis. Your Continuation Order authorizes us to ship and bill each future for Following Homotopy Paths. M. Kojima, Strongly Stable Stationary Solutions in Nonlinear Programs. H. Jürgens et al., Topological Perturbations in the Numerical Study of Nonlinear Eigenvalue and Bifurcation Problems. J. Whalley and J. Piggott, General Equilibrium Analysis of Taxation Policy. J. G. MacKinnon, Solving Urban General Equilibrium Models by Fixed Point Methods. C. R. Engles, Economic Equilibrium under Deformation of the Economy.

1980, 424 pp., \$22.50 ISBN: 0-12-590240-9

Point Arithmetic Standard. D. Klaua, Interval Components of Non-Archimedean Number Systems. S. Markov, Interval Differential Equations. R. E. Moore, New Results on Nonlinear Systems. H. Ratschek, Optimal Approximations in Interval Analysis. B. Sendov, Some Topics of Segment Analysis. F. Stummel, Rounding Error in Gaussian Elimination of Tridiagonal Linear Systems. Survey of Results. Plus 30 Contributed Lectures.

1980, 554 pp., **\$29**.50 ISBN: 0-12-518850-1

volume in the series automatically, immediately upon publication. This order will remain in effect until cancelled. Specify the volume number or title with which your order is to begin.

Send payment with order and save postage and handling. Prices are in U.S. dollars and are subject to change without notice.

ACADEMIC PRESS, INC.

A Subsidiary of Harcourt Brace Jovanovich, Publishers 111 FIFTH AVENUE, N.Y., N.Y. 10003 • 24-28 OVAL ROAD, LONDON NW1 7DX

American Mathematical Society



The AMERICAN MATHEMATICAL SOCIETY, founded in 1888, is the oldest society in the United States devoted to promoting the interests of mathematical scholarship and research. The Society serves its membership by publishing books and journals, holding meetings, and providing reviewing, indexing, employment information, and other services useful to the mathematical community.

The membership of the AMS is approximately 20,000. This includes more than 3,500 members who live outside of North America.

privileges of membership

- The opportunity to present and to hear original research papers at mathematics meetings held throughout the United States and Canada.
- Free subscriptions to the NOTICES and the BULLETIN (New Series), journals devoted to the publication of news items, research papers, and announcements of interest to mathematicians.
- A free copy of the COMBINED MEMBERSHIP LIST biennially.

Reduced subscription rates to the following journals published by the AMS: ABSTRACTS OF PAPERS PRESENTED TO THE AMS CURRENT MATHEMATICAL PUBLICATIONS MATHEMATICAL REVIEWS MATHEMATICS OF COMPUTATION MATHEMATICS OF THE USSR-IZVESTIJA MATHEMATICS OF THE USSR-SBORNIK MEMOIRS OF THE AMERICAN MATHEMATICAL SOCIETY PROCEEDINGS OF THE AMERICAN MATHEMATICAL SOCIETY PROCEEDINGS OF THE STEKLOV INSTITUTE OF MATHEMATICS SOVIET MATHEMATICS-DOKLADY THEORY OF PROBABILITY AND MATHEMATICAL STATISTICS TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOCIETY VESTNIK OF THE LENINGRAD UNIVERSITY (MATHEMATICS)

Fifty percent price reduction to individual members on most of the books published by the Society.

Reduced subscription rates to several non-AMS journals.

Minimum annual dues range from \$10 to \$48 based upon employment status.

FOR FURTHER INFORMATION AND MEMBERSHIP APPLICATION

American Mathematical Society

P. O. Box 6248, Providence, Rhode Island 02940

Arne Fransén, Addendum and Corrigendum to "High-Precision Values of the	
Gamma Function and of Some Related Coefficients"	233
Reviews and Descriptions of Tables and Books	237
Shampine and Gordon 12, Brezinski 13, Kennedy and Gentle 14	

No microfiche supplement in this issue

MATHEMATICS OF COMPUTATION TABLE OF CONTENTS

July 1981

James H. Bramble, The Lagrange Multiplier Method for Dirichlet's Problem	1
Juhani Pitkäranta, The Finite Element Method With Lagrange Multipliers for Do-	13
M Mardin and I Babyle On a Directional Reduction Method I. The Orti	13
M. Vogenus and I. Babuska, On a Dimensional Reduction Method. I. The Opti- mal Selection of Basis Functions	31
M. Vogelius and I. Babuška, On a Dimensional Reduction Method. II. Some Ap-	47
proximation-1 neoretic Results	41
D. L. Hicks, Hydrocode Subcycling Stability	69
Alan E. Berger, Jay M. Solomon and Melvyn Ciment, An Analysis of a Uniformly Accurate Difference Method for a Singular Perturbation Problem	79
Athena Makroglou, A Block-by-Block Method for Volterra Integro-Differential Equations With Weakly-Singular Kernel.	95
M. Madalena Martins, Note on Irreducible Diagonally Dominant Matrices and the Convergence of the AOR Iterative Method	101
Y. Saad, Krylov Subspace Methods for Solving Large Unsymmetric Linear Systems.	105
James A Pennline Improving Convergence Rate in the Method of Successive Ap-	all get
proximations	127
C. B. Dunham and Jack Williams, Rate of Convergence of Discretization in Chebyshev Approximation	135
P Lancaster and K Salkauskas Surfaces Generated by Moving Least Squares	
Methods	141
J. Marshall Ash and Roger L. Jones, Optimal Numerical Differentiation Using Three Function Evaluations	159
Bing-Yuan Ting and Yudell L. Luke. Computation of Integrals With Oscillatory and	
Singular Integrands	169
B. Mond, On Algorithmic Equivalence in Linear Fractional Programming	185
John P. Boyd. The Rate of Convergence of Chebyshev Polynomials for Functions	
Which Have Asymptotic Power Series About One Endpoint	189
J. P. Delahaye, Automatic Selection of Sequence Transformations	197
C. J. Smyth, On the Measure of Totally Real Algebraic Integers. II	205
Rudolf A. Mathon, Kevin T. Phelps and Alexander Rosa, A Class of Steiner Triple	A Carrie
Systems of Order 21 and Associated Kirkman Systems	209
A. J. W. Duijvestijn and P. Leeuw, Lowest Order Squared Rectangles and Squares	the state
With the Largest Element Not on the Boundary	223
Robert Baillie, G. Cormack and H. C. Williams, The Problem of Sierpiński Concern-	
$\log k \cdot 2^n + 1$	229