VOLUME 65 NUMBER 214 APRIL 1996

# MATHEMATICS OF COMPUTATION

AMERICAN MATHEMATICAL SOCIETY

**EDITED BY**

James H. Bramble
Susanne C. Brenner
Howard Elman
Richard S. Falk
Walter Gautschi
Daniel W. Lozier
James N. Lyness
Harald Niederreiter
Syvert P. Nørsett
Andrew M. Odlyzko
John E. Osborn
Stanley Osher
Carl Pomerance
René Schoof
L. Ridgway Scott
Daniel Shanks
Chi-Wang Shu
Frank Stenger
Hans J. Stetter
G. W. Stewart
Nico M. Temme
Vidar Thomée
Lars B. Wahlbin, *Managing Editor*
Joseph D. Ward
Hugh C. Williams
John W. Wrench, Jr.
Stephen J. Wright

PROVIDENCE, RHODE ISLAND USA

ISSN 0025-5718

**Mathematics of Computation**

This journal publishes research articles in computational mathematics. Areas covered include numerical analysis, the application of computational methods, algorithms for advanced computer architectures, computational number theory and algebra, and related fields. Table errata and reviews of books in areas related to computational mathematics are also included.

**Subscription information.** *Mathematics of Computation* is published quarterly. Beginning in January 1996 *Mathematics of Computation* is accessible from e-MATH via the World Wide Web at the URL `http://www.ams.org/publications/`. Subscription prices for Volume 65 (1996) are as follows: for paper delivery, $290 list, $232 institutional member, $261 corporate member, $189 MAA & SIAM members; $174 individual member; for electronic delivery, $261 list, $209 institutional member, $235 corporate member, $170 MAA & SIAM members, $157 individual member; for combination paper and electronic delivery, $334 list, $267 institutional member, $301 corporate member, $217 MAA & SIAM members, $200 individual member. If ordering the paper product, add $9 for surface delivery outside the United States and India; $18 to India. Expedited delivery to destinations in North America $13; elsewhere $40.

**Back number information.** For back issues see the *AMS Catalog of Publications*.

Subscriptions and orders should be addressed to the American Mathematical Society, P.O. Box 5904, Boston, MA 02206-5904. *All orders must be accompanied by payment.* Other correspondence should be addressed to P.O. Box 6248, Providence, RI 02940-6248.

**Unpublished Mathematical Tables.** The editorial office of the journal maintains a repository of Unpublished Mathematical Tables (UMT).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 Lars B. Wahlbin, Managing Editor, Mathematics of Computation, Center for Applied Mathematics, 657 Frank H. T. Rhodes Hall, Cornell University, Ithaca, NY 14853-3801.

**Copying and reprinting.** Material in this journal may be reproduced by any means for educational and scientific purposes without fee or permission with the exception of reproduction by services that collect fees for delivery of documents and provided that the customary acknowledgment of the source is given. This consent does not extend to other kinds of copying for general distribution, for advertising or promotional purposes, or for resale. Requests for permission for commercial use of material should be addressed to the Assistant to the Publisher, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. Requests can also be made by e-mail to `reprint-permission@ams.org`.

Excluded from these provisions is material in articles for which the author holds copyright. In such cases, requests for permission to use or reprint should be addressed directly to the author(s). (Copyright ownership is indicated in the notice in the lower right-hand corner of the first page of each article.)

---

*Mathematics of Computation* is published quarterly by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2213. Second-class postage is paid at Providence, Rhode Island. Postmaster: Send address changes to Mathematics of Computation, American Mathematical Society, P. O. Box 6248, Providence, RI 02940-6248.

© 1996 by the American Mathematical Society. All rights reserved.

This journal is indexed in *Science Citation Index*®, *SciSearch*®, *Research Alert*®, *CompuMath Citation Index*®, and *Current Contents*®/*Physical, Chemical & Earth Sciences*.

⊗ The paper used in this book is acid-free and falls within the guidelines established to ensure permanence and durability.

♻ Printed on recycled paper.

10 9 8 7 6 5 4 3 2 1 01 00 99 98 97 96

## Editorial Information

As of January 31, 1996, the backlog for this journal was approximately 1 issue. This estimate is the result of dividing the number of manuscripts for this journal in the Providence office that have not yet gone to the printer on the above date by the average number of articles per issue over the previous twelve months, reduced by the number of issues published in six months (the time necessary for editing and composing a typical issue).

A Copyright Transfer Agreement is required before a paper will be published in this journal. By submitting a paper to this journal, authors certify that the manuscript has not been submitted to nor is it under consideration for publication by another journal, conference proceedings, or similar publication.

## Information for Authors and Editors

The first page must consist of a *descriptive title*, followed by an *abstract* that summarizes the article in language suitable for workers in the general field (algebra, analysis, etc.). The *descriptive title* should be short, but informative; useless or vague phrases such as "some remarks about" or "concerning" should be avoided. The *abstract* must be brief and reasonably self-contained. Included with the footnotes to the paper, there should be the 1991 *Mathematics Subject Classification* representing the primary and secondary subjects of the article. This may be followed by a list of *key words and phrases* describing the subject matter of the article and taken from it. A list of classifications may be found in the annual index of *Mathematical Reviews*, published with the December issue starting in 1990. Journal abbreviations used in bibliographies are also listed in the latest *Mathematical Reviews* annual index. The classifications and the journal abbreviations are accessible from e-MATH via the World Wide Web at the URL `http://www.ams.org/` or via telnet: `telnet e-math.ams.org` (login and password are `e-math`). The classifications are available as a browsable list and the journal abbreviations are available through a search tool. When the manuscript is submitted, authors should supply the editor with electronic addresses if available. These will be printed after the postal address at the end of each article.

**TEX files available upon request.** Authors may request a copy of the TEX files of their papers by sending e-mail to `file-request@ams.org` or by contacting the Editorial Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. The request should include the title of the paper, the name(s) of the author(s), the name of the publication in which the paper has or will appear, and the volume and issue numbers if known. The TEX file will be sent to the author making the request after the article goes to the printer. If the requestor can receive Internet e-mail, please include the e-mail address to which the file should be sent. Otherwise please indicate a diskette format and postal address to which a disk should be mailed. **Note:** Because TEX production at the AMS sometimes requires extra fonts and macros that are not yet publicly available, TEX files cannot be guaranteed to run through the author's version of TEX without errors. The AMS regrets that it cannot provide support to eliminate such errors in the author's TEX environment.

**Electronically Prepared Manuscripts.** The AMS encourages submission of electronically prepared manuscripts in $\mathcal{AMS}$-TEX or $\mathcal{AMS}$-LATEX because properly prepared electronic manuscripts save the author proofreading time and move more quickly through the production process. To this end, the Society has prepared author packages for each AMS publication. Author packages include instructions for preparing electronic manuscripts, the *AMS Author Handbook*, samples, and a style file that generates the particular design specifications of that publication series for both $\mathcal{AMS}$-TeX and $\mathcal{AMS}$-LATEX.

Those authors who make use of these style files from the beginning of the writing process will further reduce their own efforts. Electronically submitted manuscripts prepared in plain TEX or LATEX are normally not acceptable due to the high amount of technical time required to insure that the file will run properly through the AMS in-house production system. Users of plain TEX should have little difficulty learning $\mathcal{AMS}$-TEX, and LATEX

users will find that $\mathcal{AMS}$-LaTeX is the same as LaTeX with additional commands to simplify the typesetting of mathematics.

Authors may retrieve an author package from e-MATH via the World Wide Web at the URL `http://www.ams.org/tex/` or via telnet: `telnet e-math.ams.org` (login and password are `e-math`). The author package can also be obtained free of charge by sending e-mail to `pub@ams.org` (Internet) or from the Publication Division, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. When requesting an author package, please specify $\mathcal{AMS}$-TeX or $\mathcal{AMS}$-LaTeX, Macintosh or IBM (3.5) format, and the publication in which your paper will appear. Please be sure to include your complete mailing address.

At the time of submission, authors should indicate if the paper has been prepared using $\mathcal{AMS}$-TeX or $\mathcal{AMS}$-LaTeX and provide the Managing Editor with a paper manuscript that matches the electronic manuscript. The final version of the electronic manuscript should be sent to the Providence office immediately after the paper has been accepted for publication. The author should also send the final version of the paper manuscript to the Managing Editor, who will forward a copy to the Providence office. Editors will require authors to send their electronically prepared manuscripts to the Providence office in a timely fashion. Electronically prepared manuscripts can be sent via e-mail to `pub-submit@ams.org` (Internet) or on diskette to the Editorial Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248. When submitting an electronic manuscript, please be sure to include a message indicating in which publication the paper has been accepted. No corrections will be accepted electronically. Authors must mark their changes on their proof copies and return them to the Providence office. Complete instructions on how to submit files are included in the author package.

**Electronic graphics.** Figures may be submitted to the AMS in an electronic format. The AMS recommends that graphics created electronically be saved in Encapsulated PostScript (EPS) format. This includes graphics originated via a graphics application as well as scanned photographs or other computer-generated images.

If the graphics package used does not support EPS output, the graphics file should be saved in one of the standard graphics formats—such as TIFF, PICT, GIF, etc.—rather than in an application-dependent format. Graphics files submitted in an application-dependent format are not likely to be used. No matter what method was used to produce the graphic, it is necessary to provide a paper copy to the AMS.

Authors using graphics packages for the creation of electronic art should also avoid the use of any lines thinner than 0.5 points in width. Many graphics packages allow the user to specify a "hairline" for a very thin line. Hairlines often look acceptable when proofed on a typical laser printer. However, when produced on a high-resolution laser imagesetter, hairlines become nearly invisible and will be lost entirely in the final printing process.

Screens should be set to values between 15% and 85%. Screens which fall outside of this range are too light or too dark to print correctly.

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. All contributions intended for publication and all books for review should be addressed to Lars B. Wahlbin, Managing Editor, Mathematics of Computation, Center for Applied Mathematics, 657 Frank H. T. Rhodes Hall, Cornell University, Ithaca, NY 14853-3801. The date received, which is published with the final version of an accepted paper, is the date received in the office of the Managing Editor, and it is the responsibility of the author to submit manuscripts directly to this office.

Any inquiries concerning a paper that has been accepted for publication should be sent directly to the Editorial Department, American Mathematical Society, P.O. Box 6248, Providence, RI 02940-6248.

**Editorial Committee**

ANDREW M. ODLYZKO, AT&T Bell Laboratories, 600 Mountain Avenue, Murray Hill, NJ 07974; *E-mail*: amo@research.att.com

STANLEY OSHER, Department of Mathematics, University of California, Los Angeles, CA 90024; *E-mail*: sjo@math.ucla.edu

G. W. STEWART, Department of Computer Science, University of Maryland, College Park, MD 20742; *E-mail*: stewart@thales.cs.umd.edu

LARS B. WAHLBIN, Chairman. Center for Applied Mathematics, 657 Frank H. T. Rhodes Hall, Cornell University, Ithaca, NY 14853-3801; *E-mail*: awahlbin@cam.cornell.edu

**Board of Associate Editors**

JAMES H. BRAMBLE, Department of Mathematics, Texas A & M University, College Station, TX 77843-3368; *E-mail*: bramble@math.tamu.edu

SUSANNE C. BRENNER, Department of Mathematics, University of South Carolina, Columbia, SC 29208; *E-mail*: brenner@math.sc.edu

HOWARD ELMAN, Department of Computer Science, University of Maryland, College Park, MD 20742; *E-mail*: elman@cs.umd.edu

RICHARD S. FALK, Department of Mathematics, Rutgers University, New Brunswick, NJ 08903-2101; *E-mail*: falk@math.rutgers.edu

WALTER GAUTSCHI, Department of Computer Sciences, Purdue University, West Lafayette, IN 47907; *E-mail*: wxg@cs.purdue.edu

DANIEL W. LOZIER, Applied and Computational Mathematics Division, National Institute of Standards and Technology, Gaithersburg, MD 20899-0001; *E-mail*: dlozier@nist.gov

JAMES N. LYNESS, Mathematics and Computer Science Division, Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439; *E-mail*: lyness@mcs.anl.gov

HARALD NIEDERREITER, Institute for Information Processing, Austrian Academy of Sciences, Sonnenfelsgasse 19, A-1010 Vienna, Austria; *E-mail*: nied@qiinfo.oeaw.ac.at

SYVERT P. NØRSETT, Division of Numerical Mathematics, The University of Trondheim and The Norwegian Institute of Technology, Alfred Getz vei 1, N-7034 Trondheim-NTH, Norway; *E-mail*: norsett@imf.unit.no

JOHN E. OSBORN, Department of Mathematics, University of Maryland, College Park, MD 20742; *E-mail*: jeo@julia.umd.edu

CARL POMERANCE, Department of Mathematics, The University of Georgia, Athens, GA 30602; *E-mail*: carl@math.uga.edu

RENÉ SCHOOF, Dipartimento di Matematica, 2ª Università di Roma "Tor Vergata", I-00133 Roma, Italy; *E-mail*: schoof@volterra.science.unitn.it; and schoof@fwi.uva.nl

L. RIDGWAY SCOTT, Department of Mathematics, University of Houston, Houston, TX 77204-3476; *E-mail*: scott@casc.math.uh.edu

DANIEL SHANKS, Department of Mathematics, University of Maryland, College Park, MD 20742; *E-mail*: dns@gaby.umd.edu

CHI-WANG SHU, Applied Mathematics Division, Brown University, Providence, RI 02912-0001; *E-mail*: shu@cfm.brown.edu

FRANK STENGER, Department of Computer Science, University of Utah, Salt Lake City, UT 84112; *E-mail*: stenger@cs.utah.edu

HANS J. STETTER, Institut für Numerische Mathematik, Technische Universität Wien, Wiedner Hauptstrasse 6-10, A-1040, Wien, Austria; *E-mail*: stetter@uranus.tuwien.ac.at

NICO M. TEMME, Stichting Mathematisch Centrum, Centrum voor Wiskunde en Informatica, Kruislaan 413, 1098 SJ Amsterdam, The Netherlands; *E-mail*: nicot@cwi.nl

VIDAR THOMÉE, Mathematics Department, Chalmers University of Technology, S-412 96 Göteborg, Sweden; *E-mail*: thomee@math.chalmers.se

JOSEPH D. WARD, Department of Mathematics, Texas A & M University, College Station, TX 77843-3368; *E-mail*: jward@math.tamu.edu

HUGH C. WILLIAMS, Department of Computer Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2; *E-mail*: Hugh_Williams@csmail.cs.umanitoba.ca

JOHN W. WRENCH, JR., 102 Mt. Olivet Boulevard, Frederick, MD 21701

STEPHEN J. WRIGHT, Mathematics and Computer Science Division, Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439; *E-mail*: wright@mcs.anl.gov

(Continued from back cover)

**Günter Löh and Wolfgang Niebuhr,** A new algorithm for constructing large Carmichael numbers ..... 823
**P. Erdős and Mordechai Lewin,** $d$-complete sequences of integers ..... 837
**David W. Boyd,** On beta expansions for Pisot numbers ..... 841
**David W. Boyd,** On the beta expansion for Salem numbers of degree 6 .. 861
**Reviews and Descriptions of Tables and Books** ..... 877
Brenner and Scott **14**, Friedman and Littman **15**, Dongarra and Tourancheau, Editors **16**, Gander and Hřebíček **17**, Abell and Braselton **18**, Mangasarian **19**, Nesterov and Nemirovskii **20**, Axelsson **21**, Bini and Pan **22**, Micchelli **23**, Chui, Montefusco and Puccio, Editors **24**, Farin **25**, Sapidis, Editor **26**, Krishna, Krishna, Lin and Sun **27**, Sloane and Ploufee **28**
**Supplement to** "On the beta expansion for Salem numbers of degree 6" by **David W. Boyd** ..... S29

No microfiche supplement in this issue

MATHEMATICS OF COMPUTATION

CONTENTS

Vol. 65, No. 214 April 1996

**Torgeir Rusten, Panayot S. Vassilevski, and Ragnar Winther,** Interior penalty preconditioners for mixed finite element approximations of elliptic problems ..... 447

**Zhangxin Chen, Richard E. Ewing, and Raytcho Lazarov,** Domain decomposition algorithms for mixed methods for second-order elliptic problems ..... 467

**Donald A. French and Todd E. Peterson,** A continuous space-time finite element method for the wave equation ..... 491

**Laurence Halpern,** Spectral methods in polar coordinates for the Stokes problem. Application to computation in unbounded domains ..... 507

**Bernardo Cockburn and Pierre-Alain Gremaud,** A priori error estimates for numerical methods for scalar conservation laws. Part I: The general approach ..... 533

**Haim Nessyahu,** Convergence rate of approximate solutions to weakly coupled nonlinear systems ..... 575

**Yuesheng Xu and Yunhe Zhao,** An extrapolation method for a class of boundary integral equations ..... 587

**Evangelos A. Coutsias, Thomas Hagstrom, and David Torres,** An efficient spectral method for ordinary differential equations with rational function coefficients ..... 611

**Rajendra Bhatia and Ren-Cang Li,** On perturbations of matrix pencils with real spectra. II ..... 637

**R. C. Gayle and J. M. Wolfe,** Unicity in piecewise polynomial $L^1$-approximation via an algorithm ..... 647

**Peter Borwein and Tamás Erdélyi,** The integer Chebyshev problem .. 661

**Ewald Quak,** Trigonometric wavelets for Hermite interpolation ..... 683

**W. Lawton, S. L. Lee and Zuowei Shen,** An algorithm for matrix extension and wavelet construction ..... 723

**Dirk P. Laurie,** Anti-Gaussian quadrature formulas ..... 739

**Frank Emmerich,** Pseudorandom vector generation by the compound inversive method ..... 749

**Takashi Kato, Li-Ming Wu, and Niro Yanagihara,** The serial test for a nonlinear pseudorandom number generator ..... 761

**Charles H. Jepsen,** Dissections of $p : q$ rectangles ..... 771

**Hisao Taya,** Computation of $\mathbb{Z}_3$-invariants of real quadratic fields ..... 779

**Christian Wagner,** Class number 5, 6 and 7 ..... 785

**István Gaál,** Computing all power integral bases in orders of totally real cyclic sextic number fields ..... 801

(*Continued on inside back cover*)

0025-5718(199604)65:214;1-C