SCIENTIFIC COMPUTING
VALIDATED NUMERICS
INTERVAL METHODS

Edited by

WALTER KRÄMER
University of Wuppertal, Germany

JÜRGEN WOLFF V. GUDENBERG
University of Würzburg, Germany

Kluwer Academic Publishers
Boston/Dordrecht/London

Contents

Preface xi

SCAN 2000 Keynote Address The Future of Intervals 1
G. William Walster

Part I Software– and Hardware–Tools

Variable-Precision Exponential Evaluation 19
Javier Hormigo, Julio Villalba, Michael J. Schulte

Fast computation of some special integrals of mathematical physics 29
Ekatherina A. Karatsuba

Interval Input and Output 41
Eero Hyvönen

A Case for Interval Hardware on Superscalar Processors 53
James E. Stine, Michael J. Schulte

Evaluating the Impact of Accurate Branch Prediction on Interval Software 69
Ahmet Akkas, Michael J. Schulte, James E. Stine

Automatic Test Case Generation using Interval Arithmetic 81
Günter Schumacher, Armin Bantle

Part II Linear Algebra

On the Hull of the Solution Sets of Interval Linear Equations 91
Jana Konickova

Computation of Algebraic Solutions to Interval Systems via Systems of Coordinates 103
Svetoslav Markov

Towards Diagrammatic Analysis of Systems of Interval "Linear Equations" 115
Zenon Kulpa

On the Solution of Parametrised Linear Systems 127
Evgenija D. Popova

Part III Polynomials

Verified solutions of systems of nonlinear polynomial equations 141
Daniela Fausten, Wolfram Luther

Euler-like method with Weierstrass' correction 153
Miodrag S. Petkovic, Dejan V. Vranic

Part IV Set Enclosures

Guaranteed Set Computation with Subpavings 167
Michel Kieffer, Isabelle Braems, Éric Walter, Luc Jaulin

A New Intersection Algorithm for Parametric Surfaces Based on LIEs 179
Katja Bühler, Wilhelm Barth

State estimation using interval constraint propagation 191
Luc Jaulin, Isabelle Braems, Michel Kieffer, Éric Walter

Part V Global Optimization

Interval Methods for Global Optimization Using the Boxing Method 205
Andras Erik Csallner, Rudi Klatte, Dietmar Ratz, Andreas Wiethoff

A Branch-and-Prune Method for Global Optimization 215
Dimitris G. Sotiropoulos and Theodoula N. Grapsa

Simulation of a Controlled Aircraft Elevator under Sensor Uncertainties 227
Jürgen Heeks, Eberhard P. Hofer, Bernd Tibken, Karin Lunde, Klaus Thorwart

Part VI Control

Traditional parameter estimation versus estimation of guaranteed parameter sets 241
Eberhard P. Hofer, Bernd Tibken, Milan Vlach

Stabilizing Control Design of Nonlinear Process Involving Uncertainties 255
Mikhail Krastanov, Neli Dimitrova

Set Estimation, Computation of Volumes and Data Safety 267
Isabelle Braems, Michel Kieffer, Éric Walter, Luc Jaulin

Part VII ODE and DAE and Applications

Verified High-Order Integration of DAEs and Higher-order ODEs 281
Jens Hoefkens, Martin Berz, Kyoko Makino

About a Finite Dimensional Reduction Method for Conservative Dynamical Systems and its Applications 293
Anatoliy Prykarpatsky, Stanislaw Brzychczy, V. Samoylenko

Verified Determination of Singularities in Chemical Processes 305
Christian H. Bischof, Bruno Lang, Wolfgang Marquardt, Martin Mönnigmann

Modeling of Multibody Systems with Interval Arithmetic 317
Christian Hörsken, Holger Traczinski

Part VIII Stochastics and Probability

On the Algebraic Properties of Stochastic Arithmetic. Comparison to Interval Arithmetic 331
Rene Alt, Svetoslav Markov

Global Random Walk Simulations of Diffusion 343
Calin Vamos, Nicolae Suciu, Harry Vereecken, Olaf Nitzsche, Horst Hardelauf

Interval Computations as a Particular Case of a General Scheme Involving Classes of Probability Distributions 355
Scott Ferson, Lev Ginzburg, Vladik Kreinovich, Harry Schulte

For reliable and powerful scientific computations 367
Fabienne Jézéquel, Jean-Marie Chesneaux

Reliable representations of strange attractors 379
Dominique Michelucci

Appendix: The Referees 391

Index 393

Preface

Scan 2000, the GAMM - IMACS International Symposium on Scientific Computing, Computer Arithmetic, and Validated Numerics and Interval 2000, the International Conference on Interval Methods in Science and Engineering were jointly held in Karlsruhe, September 19-22, 2000.

The joint conference continued the series of 7 previous Scan-symposia under the joint sponsorship of GAMM and IMACS. These conferences have traditionally covered the numerical and algorithmic aspects of scientific computing, with a strong emphasis on validation and verification of computed results as well as on arithmetic, programming, and algorithmic tools for this purpose.

The conference further continued the series of 4 former Interval conferences focusing on interval methods and their application in science and engineering. The objectives are to propagate current applications and research as well as to promote a greater understanding and increased awareness of the subject matters.

The symposium was held in Karlsruhe the European cradle of interval arithmetic and self-validating numerics and attracted 193 researchers from 33 countries. 12 invited and 153 contributed talks were given. But not only the quantity was overwhelming we were deeply impressed by the emerging maturity of our discipline. There were many talks discussing a wide variety of serious applications stretching all parts of mathematical modelling. New eficient, publicly available or even commercial tools were proposed or presented, and also the foundations of the theory of intervals and reliable computations were considerably strengthened.

Hence, a possible subdivision of this book might have been according to the following headlines:

- strengthen the theory
- improve the tools
- perform applications

Another observation is that the talks were concerned not only with developing enclosure methods, but also transferred the mechanisms and design process known from these areas to other fields. And, of course, there were new applications of well known enclosure methods.

The 31 contributions to this proceedings volume were carefully selected out of a much larger number of submissions. A thorough referee process has been installed, and we take the opportunity to thank all the referees for their detailed comments delivered in time.

The book opens with a historical review and an outline of the coming perspectives of intervals and reliable computations by G.W. Walster. In the first section, then, efficient algorithms for elementary functions and hardware devices are considered. The section is finished by an article that shows how the principles of enclosure methods can be applied in test strategies for scientific computations.

The second section deals with the solution of linear systems. Surprisingly enough that all the authors consider a kind of generalized arithmetic.

The treatment of polynomial equations and the sharp enclosure of sets, although difficult tasks in their own, may be considered as two of the basic ingredients for two traditional application areas: global optimization and control theory. Hence, the four topics are presented in this order.

Solutions of differential equations that model dynamic processes are the topic of the next 4 papers.

The final section is devoted to the treatment of uncertain data, in particular the relation of interval and stochastic methods is investigated.

A final "Dankeschön" to Ulrich Kulisch and the organizing committee of the symposium. We further thank all those people who helped with the publication of the proceedings, the authors, the referees, the early subscribers and the technical staff, in particular Markus Grimmer.

WALTER KRÄMER, JÜRGEN WOLFF V. GUDENBERG

Links to some freely available interval software

- C-XSC with Toolbox for Verified Computing (current versions):
  http://www.math.uni-wuppertal.de/~xsc/xsc/download.html
- Interval libraries filib and filib++:
  http://www.math.uni-wuppertal.de/wrswt/software.html
- GLOBSOL: http://studsys.mscs.mu.edu/~globsol/
- PROFIL/BIAS:
  http://www.ti3.tu-harburg.de/~knueppel/profil/index_e.html
- INTLAB: http://www.ti3.tu-harburg.de/~rump/intlab/
- INTLIB: ftp://interval.louisiana.edu/pub/interval_math/intlib
- PASCAL-XSC with Toolbox for Verified Computing:
  http://www.math.uni-wuppertal.de/~xsc/xsc/download.html
- Sun Forte Fortran/HPC and C++ compilers:
  CD in this book, see also: http://www.sun.com/forte/index.html

Further links to interval software are available under:
http://www.cs.utep.edu/interval-comp/intsoft.html

About the enclosed CD

The enclosed CD ROM contains a full set of the latest version of Sun's Forte^{TM} Developer 6 update 2 compilers and productivity tools which supports Interval Arithmetic in both Fortran 95 and C++. A 30-day trial set of license tokens can be obtained at no cost and if you decide to purchase the product, reinstallation of the software is unnecessary.

Forte Developer 6 software is an outstanding solution for software development on the Solaris^{TM} Operating Environment for both individuals and teams of software developers. It is a comprehensive, integrated, development environment that helps you build high-performance, reliable, scalable, open, applications more rapidly and efficiently with GUI- and CLI-based tools. Interval Arithmetic is supported as a native data type in Fortran 95 and as a class library in C++.