Numerical Toolbox For Verified Computing I Basic Numerical Problems Theory Algorithms And Pasca

Dieses Lehrbuch gibt dem Studenten einen Überblick über alle wichtigen Lebensräume des Meeres: von den Küstengebieten bis hin zur Tiefsee und dem Meeresboden, von den Packeiszonen bis zu den Korallenriffen. Es setzt den Schwerpunkt auf diejenigen Lebensräume im Meer, die die großen Flächen der Erdoberfläche ausmachen und eine entsprechend große Bedeutung für die Biosphäre der Erde haben - z.B. bei der aktuellen Diskussion darüber, wieviel Kohlendioxid die Weltmeere aufnehmen können.

This self-contained text is a step-by-step introduction and a complete overview of interval computation and result verification, a subject whose importance has steadily increased over the past many years. The author, an expert in the field, gently presents the theory of interval analysis through many examples and exercises, and guides the reader from the basics of the theory to current research topics in the mathematics of computation. Contents Preliminaries Real intervals Interval vectors, interval matrices Expressions, P-contraction, ?-inflation Linear systems of equations Nonlinear systems of equations Eigenvalue problems Automatic differentiation Complex intervals

Formal Design Theory (PDT) is a mathematical theory of design. The main goal of PDT is to develop a domain independent core model of the design process. The book focuses the reader's attention on the process by which ideas originate and are developed into workable products. In developing PDT, we have been striving toward what has been expressed by the distinguished scholar Simon (1969): that "the science of design is possible and some day we will be able to talk in terms of well-established theories and practices. " The book is divided into five interrelated parts. The conceptual approach is presented first (Part I); followed by the theoretical foundations of PDT (Part II), and from which the algorithmic and pragmatic implications are deduced (Part III). Finally, detailed case-studies illustrate the theory and the methods of the design process (Part IV), and additional practical considerations are evaluated (Part V). The generic nature of the concepts, theory and methods are validated by examples from a variety of disciplines. FDT explores issues such as: algebraic representation of design artifacts, idealized design process cycle, and computational analysis and measurement of design process complexity and quality. FDT's axioms convey the assumptions of the theory about the nature of artifacts, and potential modifications of the artifacts in achieving desired goals or functionality. By being able to state these axioms explicitly, it is possible to derive theorems and corollaries, as well as to develop specific analytical and constructive methodologies.

This book concerns modern methods in scientific computing and linear algebra, relevant to image and signal processing. For these applications, it is important to consider ingredients such as: (1) sophisticated mathematical models of the problems, including a priori knowledge, (2) rigorous mathematical theories to understand the difficulties of solving problems which are ill-posed, and (3) fast algorithms for either real-time or data-massive computations. Such are the topics brought into focus by these proceedings of the Workshop on Scientific Computing (held in Hong Kong on March 10-12, 1997, the sixth in such series of Workshops held in Hong Kong since 1990), where the major themes were on numerical linear algebra, signal processing, and image processing.

This book constitutes the refereed proceedings of the Second International Workshop on Practical Aspects of Declarative Languages, PADL 2000, held in Boston, MA, USA in January 2000. The 21 revised full papers presented were carefully reviewed and selected from a total of 36 submissions. The papers are organized in topical sections on functional programming, functional-logic programming, logic programming, innovative applications, constraint programming and constraint solving, and systems applications.

A large amount of the capacity of today’s computers is used for computations that can be described as computations involving real numbers. In this book, the focus is on a problem arising particularly in real number computations: the problem of veri?edor reliablecomputations. Since real numbersare objects c- taining an in?nite amount of information, they cannot be represented precisely on a computer. This leads to the well-known problems caused by unveri?ed - plementations of real number algorithms using ?nite precision. While this is t- ditionally seen to be a problem in numerical mathematics, there are also several scienti?c communities in computer science that are dealing with this problem. This book is a follow-up of the Dagstuhl Seminar 06021 on “Reliable Imp- mentation of Real Number Algorithms: Theory and Practice,” which took place January 8–13, 2006. It was intended to stimulate an exchange of ideas between the di?erent communities that deal with the problem of reliable implementation of real number algorithms either from a theoretical or from a practical point of view. Forty-eight researchers from many di?erent countries and many di?erent disciplines gathered in the castle of Dagstuhl to exchange views and ideas, in a relaxed atmosphere. The program consisted of 35 talks of 30 minutes each, and of three evening sessions with additional presentations and discussions. There were also lively discussions about di?erent theoretical models and practical - proaches for reliable real number computations. Targeted audience • Specialists in numerical computations, especially in numerical optimiza tion, who are interested in designing algorithms with automatie result ver ification, and who would therefore be interested in knowing how general their algorithms cali in principle be. • Mathematicians and computer scientists who are interested in the theory 0/ computing and computational complexity, especially computational com plexity of numerical computations. • Students in

applied mathematics and computer science who are interested in computational complexity of different numerical methods and in learning general techniques for estimating this computational complexity. The book is written with all explanations and definitions added, so that it can be used as a graduate level textbook. What this book .is about Data processing. In many real-life situations, we are interested in the value of a physical quantity y that is diflicult (or even impossible) to measure directly. For example, it is impossible to directly measure the amount of oil in an oil field or a distance to a star. Since we cannot measure such quantities directly, we measure them indirectly, by measuring some other quantities Xi and using the known relation between y and Xi'S to reconstruct y. The algorithm that transforms the results Xi of measuring Xi into an estimate fj for y is called data processing.

In the last decades, various mathematical problems have been solved by computer-assisted proofs, among them the Kepler conjecture, the existence of chaos, the existence of the Lorenz attractor, the famous four-color problem, and more. In many cases, computer-assisted proofs have the remarkable advantage (compared with a “theoretical” proof) of additionally providing accurate quantitative information. The authors have been working more than a quarter century to establish methods for the verified computation of solutions for partial differential equations, mainly for nonlinear elliptic problems of the form -?u=f(x,u,?u) with Dirichlet boundary conditions. Here, by “verified computation” is meant a computer-assisted numerical approach for proving the existence of a solution in a close and explicit neighborhood of an approximate solution. The quantitative information provided by these techniques is also significant from the viewpoint of a posteriori error estimates for approximate solutions of the concerned partial differential equations in a mathematically rigorous sense. In this monograph, the authors give a detailed description of the verified computations and computer-assisted proofs for partial differential equations that they developed. In Part I, the methods mainly studied by the authors Nakao and Watanabe are presented. These methods are based on a finite dimensional projection and constructive a priori error estimates for finite element approximations of the Poisson equation. In Part II, the computer-assisted approaches via eigenvalue bounds developed by the author Plum are explained in detail. The main task of this method consists of establishing eigenvalue bounds for the linearization of the corresponding nonlinear problem at the computed approximate solution. Some brief remarks on other approaches are also given in Part III. Each method in Parts I and II is accompanied by appropriate numerical examples that confirm the actual usefulness of the authors’ methods. Also in some examples practical computer algorithms are supplied so that readers can easily implement the verification programs by themselves.

Our aim in writing this book was to provide an extensive set of C++ programs for solving basic numerical problems with verification of the results. This C++ Toolbox for Verified Computing I is the C++ edition of the Numerical Toolbox for Verified Computing l. The programs of the original edition were written in PASCAL-XSC, a PASCAL eXtension for Scientific Computation. Since we published the first edition we have received many requests from readers and users of our tools for a version in C++. We take the view that C++ is growing in importance in the field of numeri cal computing. C++ includes C, but as a typed language and due to

its modern concepts, it is superior to C. To obtain the degree of efficiency that PASCAL-XSC provides, we used the C-XSC library. C-XSC is a C++ class library for eXtended Scientific Computing. C++ and the C-XSC library are an adequate alternative to special XSC-languages such as PASCAL-XSC or ACRITH-XSC. A shareware version of the C-XSC library and the sources of the toolbox programs are freely available via anonymous ftp or can be ordered against reimbursement of expenses. The programs of this book do not require a great deal of insight into the features of C++. Particularly, object oriented programming techniques are not required.

As suggested by the title of this book Numerical Toolbox for Verified Computing, we present an extensive set of sophisticated tools to solve basic numerical problems with a verification of the results. We use the features of the scientific computer language PASCAL-XSC to offer modules that can be combined by the reader to his/her individual needs. Our overriding concern is reliability - the automatic verification of the result a computer returns for a given problem. All algorithms we present are influenced by this central concern. We must point out that there is no relationship between our methods of numerical result verification and the methods of program verification to prove the correctness of an imple~entation for a given algorithm. This book is the first to offer a general discussion on • arithmetic and computational reliability, • analytical mathematics and verification techniques, • algorithms, and • (most importantly) actual implementations in the form of working computer routines. Our task has been to find the right balance among these ingredients for each topic. For some topics, we have placed a little more emphasis on the algorithms. For other topics, where the mathematical prerequisites are universally held, we have tended towards more in-depth discussion of the nature of the computational algorithms, or towards practical questions of implementation. For all topics, we present exam ples, exercises, and numerical results demonstrating the application of the routines presented.

This book constitutes the refereed post-proceedings of the 10th IFIP WG 2.5 Working Conference on Uncertainty Quantification in Scientific Computing, WoCoUQ 2011, held in Boulder, CO, USA, in August 2011. The 24 revised papers were carefully reviewed and selected from numerous submissions. They are organized in the following topical sections: UQ need: risk, policy, and decision making, UQ theory, UQ tools, UQ practice, and hot topics. The papers are followed by the records of the discussions between the participants and the speaker.

An update on the author's previous books, this introduction to interval analysis provides an introduction to INTLAB, a high-quality, comprehensive MATLAB toolbox for interval computations, making this the first interval analysis book that does with INTLAB what general numerical analysis texts do with MATLAB.

The number one requirement for computer arithmetic has always been speed. It is the main force that drives the technology. With increased speed larger problems can be attempted. To gain speed, advanced processors and pro gramming languages offer, for instance, compound arithmetic operations like matmul and dotproduct. But there is another side to the computational coin - the accuracy and reliability of the computed result. Progress on this side is very important, if not essential. Compound arithmetic operations, for instance, should always deliver a correct result. The user should not be obliged to perform an error analysis every

time a compound arithmetic operation, implemented by the hardware manufacturer or in the programming language, is employed. This treatise deals with computer arithmetic in a more general sense than usual. Advanced computer arithmetic extends the accuracy of the elementary floating-point operations, for instance, as defined by the IEEE arithmetic standard, to all operations in the usual product spaces of computation: the complex numbers, the real and complex intervals, and the real and complex vectors and matrices and their interval counterparts. The implementation of advanced computer arithmetic by fast hardware is examined in this book. Arithmetic units for its elementary components are described. It is shown that the requirements for speed and for reliability do not conflict with each other. Advanced computer arithmetic is superior to other arithmetic with respect to accuracy, costs, and speed.

This book constitutes the refereed proceedings of the 7th International Conference on Applied Parallel Computing, PARA 2004, held in June 2004. The 118 revised full papers presented together with five invited lectures and 15 contributed talks were carefully reviewed and selected for inclusion in the proceedings. The papers are organized in topical sections.

Enclosure methods and their applications have been developed to a high standard during the last decades. These methods guarantee the validity of the computed results. This means they are of the same standard as the rest of mathematics. The book deals with a wide variety of aspects of enclosure methods. All contributions follow the common goal to push the limits of enclosure methods forward. Topics that are treated include basic questions of arithmetic, proving conjectures, bounds for Krylow type linear system solvers, bounds for eigenvalues, the wrapping effect, algorithmic differencing, differential equations, finite element methods, application in robotics, and nonsmooth global optimization.

This book constitutes the thoroughly refereed post-proceedings of the 4th International Conference on Large-Scale Scientific Computations, LSSC 2003, held in Sozopol, Bulgaria in June 2003. The 50 revised full papers presented together with 5 invited papers were carefully reviewed and selected for inclusion in the book. The papers are organized in topical sections on preconditioning techniques, Monte Carlo methods and quasi-Monte-Carlo methods, set-value of numerics and reliable computing, environmental modeling, and large-scale computations for engineering problems.

This book constitutes the refereed post proceedings of the 16th International Symposium, SCAN 2014, held in Würzburg, Germany, in September 2014. The 22 full papers presented were carefully reviewed and selected from 60 submissions. The main concerns of research addressed by SCAN conferences are validation, verification or reliable assertions of numerical computations. Interval arithmetic and other treatments of uncertainty are developed as appropriate tools.

Data processing has become essential to modern civilization. The original data for this processing comes from measurements or from experts, and both sources are subject to uncertainty. Traditionally, probabilistic methods have been used to process uncertainty. However, in many practical situations, we do not know the corresponding probabilities: in measurements, we often only know the upper bound on the measurement errors; this is known as interval uncertainty. In turn, expert estimates often include imprecise (fuzzy) words from natural language such as "small"; this is known as fuzzy uncertainty. In this book, leading specialists on interval, fuzzy, probabilistic uncertainty and their combination describe state-of-the-art developments in their research areas. Accordingly, the book offers a valuable guide for researchers and practitioners interested in data processing under uncertainty, and an introduction to the latest trends and techniques in this

area, suitable for graduate students.

This work grew out of several years of research, graduate seminars and talks on the subject. It was motivated by a desire to make the technology accessible to those who most needed it or could most use it. It is meant to be a self-contained introduction, a reference for the techniques, and a guide to the literature for the underlying theory. It contains pointers to fertile areas for future research. It also serves as introductory documentation for a Fortran 90 software package for nonlinear systems and global optimization. The subject of the monograph is deterministic, automatically verified or r- orous methods. In such methods, directed rounding and computational fix- point theory are combined with exhaustive search (branch and bound) te- niques. Completion of such an algorithm with a list of solutions constitutes a rigorous mathematical proof that all of the solutions within the original search region are within the output list. The monograph is appropriate as an introduction to research and technology in the area, as a desk reference, or as a graduate-level course reference. Kno- edge of calculus, linear algebra, and elementary numerical analysis is assumed.

This is the revised and extended second edition of the successful basic book on computer arithmetic. It is consistent with the newest recent standard developments in the field. The book shows how the arithmetic and mathematical capability of the digital computer can be enhanced in a quite natural way. The work is motivated by the desire and the need to improve the accuracy of numerical computing and to control the quality of the computed results (validity). The accuracy requirements for the elementary floating-point operations are extended to the customary product spaces of computations including interval spaces. The mathematical properties of these models are extracted into an axiomatic approach which leads to a general theory of computer arithmetic. Detailed methods and circuits for the implementation of this advanced computer arithmetic on digital computers are developed in part two of the book. Part three then illustrates by a number of sample applications how this extended computer arithmetic can be used to compute highly accurate and mathematically verified results. The book can be used as a high-level undergraduate textbook but also as reference work for research in computer arithmetic and applied mathematics.

Accuracy and Stability of Numerical Algorithms gives a thorough, up-to-date treatment of the behavior of numerical algorithms in finite precision arithmetic. It combines algorithmic derivations, perturbation theory, and rounding error analysis, all enlivened by historical perspective and informative quotations. This second edition expands and updates the coverage of the first edition (1996) and includes numerous improvements to the original material. Two new chapters treat symmetric indefinite systems and skew-symmetric systems, and nonlinear systems and Newton's method. Twelve new sections include coverage of additional error bounds for Gaussian elimination, rank revealing LU factorizations, weighted and constrained least squares problems, and the fused multiply-add operation found on some modern computer architectures.

The SCAN conference, the International Symposium on Scientific Com puting, Computer Arithmetic and Validated Numerics, takes place bian nually under the joint auspices of GAMM (Gesellschaft fiir Angewandte Mathematik und Mechanik) and IMACS (International Association for Mathematics and Computers in Simulation). SCAN-98 attracted more than 100 participants from 21 countries all over the world. During the four days from September 22 to 25, nine highlighted, plenary lectures and over 70 contributed talks were given. These figures indicate a large participation, which was partly caused by the attraction of the organizing country, Hungary, but also the effec tive support system have

contributed to the success. The conference was substantially supported by the Hungarian Research Fund OTKA, GAMM, the National Technology Development Board OMFB and by the J6zsef Attila University. Due to this funding, it was possible to subsidize the participation of over 20 scientists, mainly from Eastern European countries. It is important that the possibly first participation of 6 young researchers was made possible due to the obtained support. The number of East-European participants was relatively high. These results are especially valuable, since in contrast to the usual 2 years period, the present meeting was organized just one year after the last SCAN-xx conference.

Advances in Parallel Computing series presents the theory and use of of parallel computer systems, including vector, pipeline, array, fifth and future generation computers and neural computers. This volume features original research work, as well as accounts on practical experience with and techniques for the use of parallel computers.

This book constitutes the thoroughly refereed post-proceedings of the 5th International Conference on Parallel Processing and Applied Mathematics, PPAM 2003, held in Czestochowa, Poland, in September 2003. The 149 papers presented were carefully selected and improved during two rounds of reviewing and revision. The papers are organized in topical sections on parallel and distributed architectures, scheduling and load balancing, performance analysis and prediction, parallel and distributed non-numerical algorithms, parallel and distributed programming, tools and environments, applications, evolutionary computing, soft computing data and knowledge management, numerical methods and their applications, multi-dimensional systems, grid computing, heterogeneous platforms, high performance numerical computation, large-scale scientific computation, and bioinformatics applications.

In recent years global optimization has found applications in many interesting areas of science and technology including molecular biology, chemical equilibrium problems, medical imaging and networks. The collection of papers in this book indicates the diverse applicability of global optimization. Furthermore, various algorithmic, theoretical developments and computational studies are presented. Audience: All researchers and students working in mathematical programming.

The analysis of singular perturbed differential equations began early in this century, when approximate solutions were constructed from asymptotic ex pansions. (Preliminary attempts appear in the nineteenth century [vD94].) This technique has flourished since the mid-1960s. Its principal ideas and methods are described in several textbooks. Nevertheless, asymptotic ex pansions may be impossible to construct or may fail to simplify the given problem; then numerical approximations are often the only option. The systematic study of numerical methods for singular perturbation problems started somewhat later - in the 1970s. While the research frontier has been steadily pushed back, the exposition of new developments in the analysis of numerical methods has been neglected. Perhaps the only example of a textbook that concentrates on this analysis is [DMS80], which collects various results for ordinary differential equations, but many

methods and techniques that are relevant today (especially for partial differential equa tions) were developed after 1980.Thus contemporary researchers must comb the literature to acquaint themselves with earlier work. Our purposes in writing this introductory book are twofold. First, we aim to present a structured account of recent ideas in the numerical analysis of singularly perturbed differential equations. Second, this important area has many open problems and we hope that our book will stimulate further investigations.Our choice of topics is inevitably personal and reflects our own main interests.

Revised and updated, this second edition of Walter Gautschi's successful Numerical Analysis explores computational methods for problems arising in the areas of classical analysis, approximation theory, and ordinary differential equations, among others. Topics included in the book are presented with a view toward stressing basic principles and maintaining simplicity and teachability as far as possible, while subjects requiring a higher level of technicality are referenced in detailed bibliographic notes at the end of each chapter. Readers are thus given the guidance and opportunity to pursue advanced modern topics in more depth. Along with updated references, new biographical notes, and enhanced notational clarity, this second edition includes the expansion of an already large collection of exercises and assignments, both the kind that deal with theoretical and practical aspects of the subject and those requiring machine computation and the use of mathematical software. Perhaps most notably, the edition also comes with a complete solutions manual, carefully developed and polished by the author, which will serve as an exceptionally valuable resource for instructors.

This book constitutes the thoroughly refereed post-proceedings of the 5th International Conference on Large-Scale Scientific Computations, LSSC 2005, held in Sozopol, Bulgaria in June 2005. The 75 revised full papers presented together with five invited papers were carefully reviewed and selected for inclusion in the book. The papers are organized in topical sections.

Mathematical modelling has become in recent years an essential tool for the prediction of environmental change and for the development of sustainable policies. Yet, many of the uncertainties associated with modelling efforts appear poorly understood by many, especially by policy makers. This book attempts for the first time to cover the full range of issues related to model uncertainties, from the subjectivity of setting up a conceptual model of a given system, all the way to communicating the nature of model uncertainties to non-scientists and accounting for model uncertainties in policy decisions. Theoretical chapters, providing background information on specific steps in the modelling process and in the adoption of models by end-users, are complemented by illustrative case studies dealing with soils and global climate change. All the chapters are authored by recognized experts in their respective disciplines, and provide a timely and uniquely comprehensive coverage of an important field.

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 efficient, publicly available or even commercial tools were proposed or presented, and also foundations of the theory of intervals and reliable computations were considerably strengthened.

The major emphasis of the Dagstuhl Seminar on “Numerical Validation in C- rent Hardware Architectures” lay on numerical validation in current hardware architecturesand softwareenvironments. The generalidea wasto bring together experts who are concerned with computer arithmetic in systems with actual processor architectures and scientists who develop, use, and need techniques from veri?ed computation in their applications. Topics of the seminar therefore included: – The ongoing revision of the IEEE 754/854 standard for ?oating-point ari- metic – Feasible ways to implement multiple precision (multiword) arithmetic and to compute the actual precision at run-time according to the needs of input data – The achievement of a similar behavior of ?xed-point, ?oating-point and - terval arithmetic across language compliant implementations – The design of robust and e?cient numerical programsportable from diverse computers to those that adhere to the IEEE standard – The development and propagation of validated special-purpose software in di?erent application areas – Error analysis in several contexts – Certi?cation of numerical programs, veri?cation and validation assessment Computer arithmetic plays an important role at the hardware and software level, when microprocessors, embedded systems, or grids are designed. The re- ability of numerical softwarestrongly depends on the compliance with the cor- sponding ?oating-point norms. Standard CISC processors follow the 1985 IEEE norm 754, which is currently under revision, but the new highly performing CELL processor is not fully IEEE compliant.

Reliable computing techniques are essential if the validity of the output of a - merical algorithm is to be guaranteed to be correct. Our society relies more and more on computer systems. Usually, our systems appear to work successfully, but there are sometimes serious, and often minor, errors. Validated computing is one essential technology to achieve increased software reliability. Formal - gor in the de?nition of data types, the computer arithmetic, in algorithm design, and in program execution allows us to guarantee that the stated problem has (or does not have) a solution in an enclosing interval we compute. If the enclosure is narrow, we are certain that the result can be used. Otherwise, we have a clear warning that the uncertainty of input

values might be large and the algorithm and the model have to be improved. The use of interval data types and al- rithms with controlled rounding and result veri?cation capture uncertainty in modeling and problem formulation, in model parameter estimation, in algorithm truncation, in operation round-o?, and in model interpretation. The techniques of validated computing have proven their merits in many scienti?c and engineering applications. They are based on solid and interesting theoretical studies in mathematics and computer science. Contributions from ?elds including real, complex and functional analysis, semigroups, probability, statistics,fuzzyintervalanalysis,fuzzylogic,automaticdi?erentiation,computer hardware, operating systems, compiler construction, programming languages, object-oriented modeling, parallel processing, and software engineering are all essential.

The two volume set LNCS 7133 and LNCS 7134 constitutes the thoroughly refereed post-conference proceedings of the 10th International Conference on Applied Parallel and Scientific Computing, PARA 2010, held in Reykjavík, Iceland, in June 2010. These volumes contain three keynote lectures, 29 revised papers and 45 minisymposia presentations arranged on the following topics: cloud computing, HPC algorithms, HPC programming tools, HPC in meteorology, parallel numerical algorithms, parallel computing in physics, scientific computing tools, HPC software engineering, simulations of atomic scale systems, tools and environments for accelerator based computational biomedicine, GPU computing, high performance computing interval methods, real-time access and processing of large data sets, linear algebra algorithms and software for multicore and hybrid architectures in honor of Fred Gustavson on his 75th birthday, memory and multicore issues in scientific computing - theory and praxis, multicore algorithms and implementations for application problems, fast PDE solvers and a posteriori error estimates, and scalable tools for high performance computing.

The authors of this Festschrift prepared these papers to honour and express their friendship to Klaus Ritter on the occasion of his sixtieth birthday. Be cause of Ritter's many friends and his international reputation among math ematicians, finding contributors was easy. In fact, constraints on the size of the book required us to limit the number of papers. Klaus Ritter has done important work in a variety of areas, especially in var ious applications of linear and nonlinear optimization and also in connection with statistics and parallel computing. For the latter we have to mention Rit ter's development of transputer workstation hardware. The wide scope of his research is reflected by the breadth of the contributions in this Festschrift. After several years of scientific research in the U.S., Klaus Ritter was ap pointed as full professor at the University of Stuttgart. Since then, his name has become inextricably connected with the regularly scheduled conferences on optimization in Oberwolfach. In 1981 he became full professor of Applied Mathematics and Mathematical Statistics at the Technical University of Mu nich. In addition to his university teaching duties, he has made the activity of applying mathematical methods to problems of industry to be centrally important.

This book constitutes the refereed proceedings of the First International Workshop on Numerical Analysis and Its Applications, WNAA'96, held in Rousse, Bulgaria, in June 1996. The 57 revised full papers presented were carefully selected and reviewed for inclusion in the volume; also included are 14 invited presentations. All in all, the book offers a wealth of new results and methods of numerical analysis applicable in computational science, particularly in computational physics and chemistry. The volume reflects

that the cooperation of computer scientists, mathematicians and scientists provides new numerical tools for computational scientists and, at the same time, stimulates numerical analysis.