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REVIEWS AND DESCRIPTIONS OF TABLES AND BOOKS

The numbers in brackets are assigned according to the American Mathematical Society classification scheme. The 2000 Mathematics Subject Classification can be found in print starting with the 1999 annual index of *Mathematical Reviews*. The classifications are also accessible from `www.ams.org/msc/`.

1[35F10, 35K15, 65M06, 65M12]—*Time-dependent partial differential equations and their numerical solution*, by Heinz-Otto Kreiss and Hedwig Ulmer Busenhart, Birkhäuser, Basel, Boston, Berlin, 2001, vi+82 pp., 24 cm, $24.95

This book contains short lecture notes summarizing the main results from the following two books: *Initial-boundary value problems and the Navier-Stokes equations* by H.-O. Kreiss and J. Lorenz, Academic Press, 1989, and *Time dependent problems and difference methods*, John Wiley & Sons, 1995. Simple examples are given to illustrate the main results. The main results are presented and some proofs demonstrating important approaches are also given. Explicit references to the relevant chapters in the two books mentioned above are given at the end of each chapter. There are four chapters in this short book: on Cauchy problems, half plane problems, difference methods, and nonlinear problems, respectively. This is a very good book for lecture notes of a condensed course on the topics of time-dependent partial differential equations and difference methods at the beginning graduate level; for example, for a summer course. It is also a good book for anyone who is interested in getting a quick start on learning these topics.

Chi-Wang Shu

2[65-02]—*Foundations of computational mathematics*, Ronald A. Devore, Arieh Iserles, and Endre Sűli (Editors), Cambridge University Press, New York, NY, 2001, viii+400 pp., 23 cm, softcover $49.95

This volume contains thirteen papers presented by plenary speakers at the 1999 conference in Oxford devoted to Foundations of Computational Mathematics. The contents are as follows.

Singularities and computation of minimizers for variational problems, J. M. Ball; *Adaptive finite element methods for flow problems*, R. Becker, M. Braack and R. Rannacher; *Newton's method and some complexity aspects of the zero-finding problem*, J.-P. Dedieu; *Kronecker's smart, little black boxes*, M. Giusti and J. Heintz; *Numerical analysis in Lie groups*, A. Iserles; *Feasibility control in nonlinear optimization*, M. Marazzi and J. Nocedal; *Six lectures on the geometric integration of ODEs*, R. I. McLachlan and G. R. Quispel; *When are integration and discrepancy tractable*? E. Novak and H. Woźniakowski; *Moving frames—in geometry, algebra, computer vision, and numerical analysis*, P. J. Olver; *Harmonic map flows and image processing*, G. Sapiro; *Statistics from computations*, H. Sigurgeirsson and A. M. Stuart; *Simulation of stochastic processes and applications*, D. Talay; *Real-time* *numerical solution to Duncan–Mortensen–Zakai equation*, S.-T. Yau and S. S.-T. Yau.

Lars B. Wahlbin

3[65-02, 65F15]—*Templates for the solution of algebraic eigenvalue problems, a practical guide*, Zhaojun Bai, James Demmel, Jack Dongarra, Axel Ruhe, and Henk van der Vorst (Editors), SIAM, Philadelphia, PA, 2000, xxix+401 pp., 25 cm, softcover $62.00

Algebraic eigenvalue problems are ubiquitous in scientific computing. Many excellent methods for computing the eigenvalues and corresponding eigenvectors of dense matrices are available in programming environments like Matlab and in libraries like LAPACK. For such problems it is rather straightforward to select the "best" method, as the choice depends on parameters that are easy to formulate and check, e.g., symmetry and band structure. Often it is the default (and fastest) operation to compute all the eigenvalues.

For very large, structured, and/or sparse problems, no single best method exists. There are several competing methods to choose between, depending on the properties of the problem. Apart from the parameters mentioned above for dense problems, the choice of algorithm is influenced by the desired spectral information, and the available operations and their cost: Can similarity transformations be performed on the matrix? Can the matrix be factorized? Can we only multiply a vector by the matrix or perhaps by its transpose? This book gives an overview of the state of the art in algorithms for large, sparse eigenvalue problems.

Based on the desired spectral information and the available operations and their cost, recommendations are given on choosing one of the algorithms. The recommendations are summarized in the form of a decision tree. The complexity of the decision problem is illustrated by the fact that the decision table for the Hermitian eigenvalue problem has six classes of methods, each with two or three variants, the choice of which depends on six parameters.

Each algorithm is presented in the form of a *template*, which is a high-level description. Apart from the algorithmic structure, information is given about when the algorithm is effective as well as estimates about the time and space required. Available refinements and user-tunable parameters are described, and ways to assess the accuracy are given. Finally, numerical examples illustrate both easy and difficult cases for each algorithm.

There is a website for the book, which describes how to access software discussed in the book (the home page was not available when this review was written).

The table of contents demonstrates the scope of the book. To give an idea of how the book is organized, we give also the section headings for a typical chapter, namely that on Hermitian eigenvalue problems.

1. Introduction
2. A brief tour of eigenproblems (30 pp.)
3. An introduction to iterative projection methods (8 pp.)
4. Hermitian eigenvalue problems (54 pp.)
   (a) Single- and multiple-vector iterations (M. Gu)
   (b) Lanczos method (A. Ruhe)
   (c) Implicitly restarted Lanczos method (R. Lehoucq and D. Sorensen)

   (d) Band Lanczos method (R. Freund)
   (e) Jacobi-Davidson methods (G. Sleijpen and H. van der Vorst)
   (f) Stability and accuracy assessments (Z. Bai and R. Li)
5. Generalized Hermitian eigenvalue problems (26 pp.)
6. Singular value decomposition (14 pp.)
7. Non-Hermitian eigenvalue problems (82 pp.)
8. Generalized non-Hermitian eigenvalue problems (48 pp.)
9. Nonlinear eigenvalue problems (34 pp.)
10. Common issues (22 pp.)
11. Preconditioning techniques (32 pp.)
12. Appendix: Of things not treated (8 pp.)
13. Bibliography (473 references)

Most of the algorithms presented have been developed over a reasonable period of time and it is likely that they are quite close to their ultimate version. So from this point of view it is appropriate that this book is published now. The book also contains one or two sections on nonstandard material, which is not yet ready to be made into numerical software. In view of the preliminary state of the work, it might have been better to omit the section on preconditioned eigensolvers (Knyazev), and consider it for possible inclusion in a second edition of the book.

The intended readership is stated to be both students and teachers, a general audience of scientists and engineers, and experts in high performance computing who want to solve the most difficult applied problems. In my opinion the book is very useful for all categories mentioned. However, it should be noted that the presentation presupposes that the reader already has a good background in numerical linear algebra.

Most of the algorithms are well known, at least for researchers in numerical analysis, and have been developed and made into numerical software during the last decade. Even if the main part of this material is already available in the literature, it has not been presented in a common framework and it has been difficult to compare different alternative methods. This book, written by some of the best experts in the field, is invaluable for anyone who wants to know the state-of-the-art algorithms for large, sparse eigenvalue problems. The availability of codes at the website of the book will make it possible for many more people to quickly take advantage of the latest research in the area (provided that the website is well maintained). I consider the book as a very important source in this field of scientific computing.

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4[35Q80, 49-01, 53-01, 65D99, 68U10]—*Geometric partial differential equations and image analysis*, by Guillermo Sapiro, Cambridge University Press, New York, NY, 2001, xxv+385 pp., 23 1/2 cm, hardcover $64.95

Introduction. Image analysis is now present and necessary in many different areas and aspects in the sciences, such as internet, compression and transmission, medical imaging, satellite imaging, video surveillance, and many others.

This book addresses important problems and applications in the field of image analysis, via variational methods, geometric partial differential equations, and differential geometry. This research area brings several new concepts into the field, providing a very fundamental and mathematically formalized approach to image analysis. State-of-the-art practical results in a large number of real problems are achieved with the techniques described in this book. These include geometric curve and surface evolution, geodesic curves and minimal surfaces, geometric diffusion of scalar and vector-valued images, diffusion on nonflat manifolds, contrast enhancement, and additional applications to image segmentation, shape analysis, image enhancement, tracking, image repair, interpolation, shape from shading, and blind deconvolution. The book is accompanied by the necessary mathematical background (including numerical analysis notions), making it very clear and self-contained. In addition, each chapter ends with a list of exercises, making it of great use as a textbook for graduate lectures and seminars. The exposition is very clear, and it is also accompanied by many illustrations, pictures, and examples of numerical results, making the explanations clear and easy to understand. The book contains methods originally proposed by the author, but also an extensive description (with adequate citations and references) of methods proposed by other authors in the field.

This book is addressed to applied mathematicians interested in image analysis, to other mathematicians working on geometric partial differential equations and differential geometry, and to researchers, practitioners and graduate students working on image processing. The book also provides excellent material for a graduate course. I think that every person interested in image analysis by partial differential equations or related fields, such as differential geometry and curve evolution, should read this book. The book is also perfectly complementary to the very few existing and related books, and the differential geometry approach makes it unique.

Content description. Chapter 1 is devoted to the basic mathematical background necessary for the reader to well understand the mathematical techniques, notations, and terminology of the book. It contains basic notions of differential geometry, partial differential equations, calculus of variations, and numerical analysis. Chapter 2 is devoted to geometric curve and surface evolution concepts, with a description of the most used geometric flows, computational aspects, and some of the applications. Chapter 3 is devoted to active contours by geometric PDE's, which is one of the most important problems in image processing. Chapters 4 and 5 are devoted to techniques of geometric diffusion of scalar and vector-valued images. Chapter 6 discusses a more recent but very interesting topic of diffusion on nonflat manifolds. Chapter 7 is devoted to contrast enhancement, and the book ends with additional applications in Chapter 8.

The author is an internationally recognized expert in the field. He is a very good lecturer and teacher, and this is reflected in the highly pedagogical style of this book.

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5[68W30, 11Yxx, 12Y05, 13Pxx]—*Fundamental problems of algorithmic algebra*, by Chee Keng Yap, Oxford University Press, New York, NY, 1999, xv+510 pp., 24 cm, hardcover $72.00

In the last few years a variety of good textbooks on computer algebra have appeared. On the introductory pages, Yap mentions fourteen such textbooks, eleven of which were published in the 1990's (a notable exception is the classic text by Borodin and Munro which dates back to 1975). This list does not (yet) mention the recent books (*Some tapas of computer algebra*, A. M. Cohen, H. Cuypers and H. Sterk (eds.), Springer, 1999; *Computational methods in commutative algebra and algebraic geometry*, W. V. Vasconcelos, Springer, 1998; *Modern computer algebra*, J. von zur Gathen and J. Gerhard, Cambridge University Press, 1999; *Polynomial algorithms in computer algebra*, F. Winkler, Springer, 1996; and *Computational commutative algebra I*, M. Kreuzer and L. Robbiano, Springer, 2001).

The title of Yap's book does not mention the words computer algebra, but in his preface he writes "The preferred name today is 'computer algebra' although I feel that 'algorithmic algebra' better emphasizes the true nature of the subject." Like most of the books referred to above, Yap's treatment stays away from too close a connection with a specific package by dealing with the algorithms on an abstract mathematical level. Algorithms are stated in natural words using mathematical concepts or in pseudocode, and their correctness and/or complexity is established in the usual definition, lemma, proposition, theorem format. By the way, the latter three kinds of statement together with proofs appear in heavily bordered boxes. This layout sets the tone for the book: it is an almost self-contained treatment of the most basic topics in computer algebra, well presented, and with good attention to complexity issues. The reader is supposed to know some abstract algebra, but little else.

The book starts out with a treatment of the notions of effective computation, complexity and (as an example) the fundamental theorem of algebra (the fact that every univariate polynomial over the complex numbers has a root). It then deals with multiplication, factorization, (sub)resultants and modular techniques for gcd and the like. After four initial chapters on these topics, the author returns to the fundamental theorem of algebra and deals with constructive field theory and roots finding of a univariate polynomial equations. Next, Sturm theory, the algebraic treatment of real roots (their signs and order of occurrence) appears, followed by two chapters on lattice reduction algorithms. The book treats matrices marginally, but devotes a chapter to linear systems, with emphasis on Hermite and Smith normal form. Then come three chapters on solving multivariate polynomial systems of equations. Here the author devotes a little more than average attention to the complexity issues. Perhaps remarkable is the last chapter (14), which deals with continued fractions applied to approximating real roots of polynomials and to interval arithmetic.

I think Yap has succeeded in bringing about a pleasant introduction to the main algorithms of computer algebra. It distinguishes itself from most others in that it is a real textbook (that is, good to use in class), introduces almost all basic topics in a palatable way, and gives a serious treatment of complexity. How useful is it compared with the many other (good) new treatises? I suppose the future will tell.

Arjeh M. Cohen

6[11Yxx, 11Txx, 94Axx, 68P25]—*Cryptography and computational number theory*, Kwok-Yan Lam, Igor Shparlinski, Huaxiong Wang, and Chaoping Xing (Editors), Birkhäuser, Basel, Switzerland, 2001, vii+378 pp., 24 cm, hardcover $109.00

This volume represents the proceedings of the Workshop on Cryptography and Computational Number Theory which was held at the National University of Singapore in November 1999. The book contains thirteen articles classified under computational number theory and fourteen articles classified under cryptography. Some papers are surveys and others present new original results. The reviewer found the surveys by D. R. Kohel on elliptic curves for cryptography, by P. Mihăilescu on testing and proving primality, by C. P. Xing on algebraic-geometry methods for constructing almost perfect sequences, and by M. I. González Vasco and M. Näslund on hard core functions to be particularly interesting and useful.

Harald Niederreiter