The book is admirably carefully written. The unreasonable references (e.g., "Proof of Theorem XY: See Exercise MN/Exercise MN: Proof of Theorem XY"), however, I found somewhat bothersome. Otherwise, the representation is clear and as didactically well structured as can already be assumed from the subdivision into the eight chapters mentioned. A pleasant layout contributes to the pleasure one surely has reading the book.

Roswitha März

8[65-02, 65Fxx]—*Computer solution of large linear systems*, by Gerard Meurant, North Holland, Amsterdam, 1999, xxii+753 pp., 23 cm, hardcover, $149.50

Two characteristics of this book are immediately evident: the table of contents is very detailed and the list of references is large, which makes the book a useful reference for someone working in the area. The chapters are well organized and it is easy to find something quickly through the table of contents if you know the name of a technique, or through browsing in the appropriate chapter if not. The index in the back of the book is rather sparse and not very helpful.

This book contains many results on estimates of eigenvalues and error bounds for symmetric positive definite systems. Some proofs are presented in each chapter to give an idea of the typical arguments used. For many theorems the reader is referred to the original work for the proof. This allows the author to present a lot of material without making the book overly large. This is not a defect as most researchers are interested in the original citation anyway. Also, since the book carries a fairly complete and up-to-date (for the mid- to late-1990s) set of algorithms with descriptions of implementations, it is easy to search in the appropriate chapter and answer the question, "Who has done work in this area before?"

This book is not intended as a text as there are no exercises, and if a proof is not presented, it tells you where to find it. Some of the material is developed in detail and is easy to follow for someone new to the field. Some of the results are not as well motivated.

Chapter 1 covers introductory material, beginning with topics in linear algebra and graph theory and progressing to issues involved in solving linear systems on computers, where exact arithmetic is not available. Sparse storage schemes, a short history on BLAS routines, and parallel machines are also presented.

The second chapter is devoted to Gaussian elimination on dense matrices. Six different algorithms are presented, which may be a bit of overkill. A lot of attention is paid to tridiagonal and block tridiagonal systems, which are the types of large systems one would solve this way. Otherwise, the chapter is rather brief. Some parallel implementation details are presented at the end.

Chapter 3 covers Gaussian elimination for sparse matrices. Graph theory is used to motivate reordering strategies. Most of this chapter is devoted to symmetric positive definite matrices, with just a little bit on nonsymmetric matrices. Admittedly, this is where the theory is best developed. There is some discussion of parallel implementations also.

Chapter 4 is a rather short chapter on fast solvers for separable PDEs. It covers mostly FFT and cyclic reduction methods.

Chapter 5 contains the classical iterative methods, such as Jacobi, Gauss–Seidel, SOR, and variations. Convergence criteria are derived, as well as convergence rates for each method. There is very little new material in this chapter, but it belongs in the book for completeness.

Chapter 6 has conjugate gradient type methods. There is a particularly detailed set of proofs on the optimality of PCG and convergence rates. There are also a lot of details on a posteriori error bounds. All of these relatively short algorithms are presented in detail.

Chapter 7 is on Krylov subspace methods for nonsymmetric systems. This chapter contains a lot of details on the algorithms, but only a few short proofs of convergence theorems are presented, and the reader is directed elsewhere for longer ones. The Arnoldi and Hessenberg algorithms are presented, along with descriptions of, and reasoning for, using modified Gram Schmidt orthogonalization and Givens rotations. FOM and GMRES and relations between the two are discussed, as is BiGCG. Generalizations of methods are discussed, including restarted and flexible versions and stabilization techniques. There are a number of plots depicting the norm of the error as a function of iteration count. These could be useful to someone for selecting a method, or for comparing results of a new method. The chapter ends with a quick presentation of some algorithms for complex linear systems and a short discussion of why parallel implementations pose problems.

Chapter 8 on preconditioning is the largest chapter in the book. Most of the chapter is devoted to methods for symmetric matrices, and mostly symmetric positive definite. It begins with a nice description of the properties sought in a preconditioner and the trade-offs involved between then. Then it launches into simple diagonal preconditioning, followed by point and block SSOR. This section contains perhaps more details than are necessary on finding an optimum relaxation parameter, including a derivation on estimates of the eigenvalues using Fourier analysis of the Poisson equation with periodic boundary conditions. Similar detail is included in analysis of incomplete Cholesky preconditioning.

There is a large section on incomplete Cholesky and its usefulness as a preconditioner for various types of matrices. Many results are presented from Axelsson's book, and the reader is referred there for some proofs. There is a good description of some reordering techniques complete with examples on rectangular domains detailing the new unknown orderings and iteration counts, computational costs, and preconditioner sizes.

The section on sparse approximate inverse preconditioners gives a good description of the guiding principles behind the most popular methods. However, there is little mention of the costs associated with constructing them, and no mention at all of their advantages over other preconditioners on parallel machines.

This chapter concludes with a discussion, including a few implementation details, of the differences between parallel and vector computers. As vector computers have been going in and out of fashion, it is nice to see at least some mention of them.

Chapter 9 covers multigrid methods. This chapter is a little disappointing. The order in which the material is presented is not as smooth as in other chapters. There is very little mention of algebraic multigrid methods.

The last chapter covers domain decomposition methods. This chapter starts, as domain decomposition did historically, with a description of an alternating Schwarz method and some convergence results for the Poisson problem. From there it heads into additive and multiplicative Schwarz methods and Schur complement methods. The most useful part of the chapter describes how domain decomposition methods can be used to construct preconditioners. The examples are all related to PDEs solved on rectangular, or at least conceptually rectangular domains. One would expect to see an example of how a domain can be broken up for solving a PDE using finite elements on an unstructured mesh. The chapter ends with a short discussion of multilevel ILU preconditioners. This again is restricted to SPD matrices.

All in all, *Computer solution of large linear systems* would make a fine reference book for engineers, computer scientists, and mathematicians working with large systems. It is most useful for those working with symmetric positive definite systems. The book presents a large number of useful algorithms, along with the important theory governing their behavior. It also does a wonderful job of citing other sources where one can fill in the details.

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9[11L05, 11L40, 65C10, 94A60, 94B05]—*Character sums with exponential functions and their applications*, by Sergei Konyagin and Igor Shparlinski, Cambridge University Press, New York, NY, 1999, viii+163 pp., 23 1/2 cm, hardcover, $49.95

The main theme of this monograph is the distribution of the powers of an integer g with $1 < g < p$ modulo a prime p. Character sums with exponential functions in the argument form the most important tool in the analysis. Many of the problems considered here are motivated by applications, and a good part of the book is devoted to applications. The book collects known results, most of them of fairly recent origin, but also presents new theorems not published before. One stated aim of the book is to stimulate further research, and this goal has certainly been reached, for instance through the many open problems that the authors pose along the way.

The first two chapters set the stage via introductory remarks and auxiliary results. Chapters 3 to 6 are devoted to the core of the theory, namely bounds for character sums with exponential functions in the argument and related bounds for Gaussian sums. Chapters 7 to 10 deal with number-theoretic applications; for instance, to multiplicative translates of sets modulo p and to class numbers of cyclotomic fields. Chapter 11 considers the important problem of the occurrence of given strings in digit expansions of rational numbers, which is connected with the Blum-Blum-Shub pseudorandom bit generator in cryptography. Applications to linear congruential pseudorandom numbers, in particular the question of the existence of good multipliers, are treated in Chapter 12. Chapters 13 and 14 are more of number-theoretic interest, whereas the distribution theorems in Chapter 15 allow very interesting applications to a "pseudo-randomized" version of the QuickSort algorithm. In the last three chapters, the treatment of upper bounds for the dimension of BCH codes is of particular relevance from the viewpoint of applications.

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