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Numerical Analysis

Mathematics of Scientific Computing

By David Kincaid and Ward Cheney

Brooks/Cole Publishers, 1991, 690pp., 0-534-13014-3

Reviewed by William Gearhart

Contents: *1. Mathematical Preliminaries 2. Computer Arithmetic 3. Solution of Nonlinear Equations 4. Solving Systems of Linear Equations 5. Selected Topics in Numerical Linear Algebra 6. Approximating Functions 7. Numerical Differentiation and Integration 8. Numerical Solution of Ordinary Differential Equations 9. Numerical Solution of Partial Differential Equations 10. Linear Programming and Related Topics*

This text offers a thorough and elegant presentation of basic topics in numerical analysis. A glance at the book may remind one of the authors' earlier undergraduate text, *Numerical Mathematics and Computing* (which is also an excellent text, by the way), but this text is somewhat more advanced and extensive. While parts of the text would be accessible to upper division undergraduates, it seems more suitable for graduate students. A student with the usual two years of calculus, a course in differential equations, and one in linear algebra would be reasonably prepared for the text. However, a student would need some mathematical maturity to be comfortable with the entire book. It seems ideal for a one or two semester course in a master's degree program.

We have used it in our master's degree program in applied mathematics with some success. It offers a treatment of basic numerical analysis, adhering to mathematical foundations. In a Ph.D. program, it would certainly be an excellent reference for students and an excellent textbook for a general introductory course in numerical analysis.

The text begins with a review of topics from calculus. The material in this chapter will benefit many beginning graduate students. The section on difference equations was wisely included. For some reason, students often seem weak in this area. A few sections of the text require preparation beyond the material in this chapter. For example, in the latter parts of the chapter on approximating functions, it would help if a student has had an introduction to normed function spaces and functionals. However, as the authors point out, sections with advanced material have been placed toward the end of the chapter, so that an instructor can conveniently include or omit them as desired.

The second chapter is about computer arithmetic, error analysis, and the notions of stability of a numerical process and conditioning of a problem. This material, typically found in numerical analysis texts, can be tedious to read. Gratefully however, the authors have written this chapter in a stimulating way that holds one's attention.

The third chapter concerns solution of nonlinear equations. This chapter deals mainly with equations in one unknown, and covers all the basic methods. Concerning solution of nonlinear systems of equations, there is a description of Newton's method, and an introduction to homotopy and continuation methods.

The next two chapters concern numerical linear algebra. Chapter four gives a substantial treatment of Gaussian elimination, including iterative refinement and analysis of roundoff errors. Also covered are iterative methods, acceleration schemes, and the method of conjugate gradients.

Chapter five covers a variety of topics, and is a useful chapter from which an instructor can select material. Included are orthogonal factorizations, singular value decomposition, and the QR method of Francis.

Chapter six covers approximation of functions and is an extensive and authoritative presentation. The early sections cover polynomial interpolation, including the use of divided differences and Hermite interpolation. The presentation of spline functions is elegant. The section on trigonometric interpolation and the fast Fourier transform is especially well organized. Also, there is a section on adaptive approximation, a topic not often found in texts. These sections, together with the later sections of this chapter covering least-square and Chebyshev approximation, interpolation in higher dimensions, and continued fractions, bring the reader nearly to the state of the art.

Chapter seven is about numerical differentiation and integration, covering basic approximation schemes, extrapolation, and adaptive integration. Also, there is an especially interesting section on approximation in the sense of Sard, and the result of Schoenberg showing how splines play a role in this theory.

Chapters eight and nine cover the solution of differential equations. There is an extensive coverage of numerical methods for ordinary differential equations, including the Runge-Kutta-Fehlberg ideas, boundary value problems, and an introduction to stiff equations. Chapter nine provides an excellent introduction to the numerical solution of partial differential equations, covering numerical methods for the three basic types: parabolic, hyperbolic and elliptic. Special features include presentations of multigrid methods and of Galerkin methods. Finally, chapter ten presents mathematical foundations of the linear programming problem, and gives the steps of the simplex method.

Overall, the style of the text is scholarly, with an emphasis on underlying mathematics. Topics are presented carefully and rigorously, and in ways that reveal the mathematical foundations of the numerical methods. Algorithmic aspects are made clear, and easily followed pseudocodes are given for important algorithms. The sections typically have numerous exercises, with many problems that serve to enhance understanding. The book is now in its second printing, and appears to be relatively free of errors.

The text offers a broad range of topics, including many that are not often found in such books. We find, for instance, an introductory but substantive discussion of homotopy and continuation methods, many current topics from approximation theory, extensive coverage of partial differential equations, including Galerkin methods and an introduction to multigrid methods. In addition to breadth, we find also that the text is written in a way that allows instructors flexibility in designing a course. Depending on how emphasis is placed, it is possible on the one hand, to offer a course focusing on the mathematical analysis of numerical processes, or, on the other hand, one that is more algorithmic, focusing on the construction and implementation numerical methods. No doubt, these features will bring the text wide classroom use and make it an excellent reference.

This text is skillfully written, by authors who are among the best in the field. Throughout, the presentation shows the unique insights that each brings to the subject. In all, it is an enjoyable text to use.

William Gearhart

William B. Gearhart received his B.S. degree in Engineering Physics and his Ph.D. in Applied Mathematics from Cornell University. He is now Professor of Mathematics at the California State University at Fullerton. His research interests and publications are in numerical analysis, approximation theory, and mathematical modeling. In 1991, he was a recipient of a Polya Award for expository writing from the Mathematical Association of America–*ed.*