Numerical Methods in Engineering with MATLAB®

Second Edition

Numerical Methods in Engineering with MATLAB® is a text for engineering students and a reference for practicing engineers. The choice of numerical methods was based on their relevance to engineering problems. Every method is discussed thoroughly and illustrated with problems involving both hand computation and programming. MATLAB M-files accompany each method and are available on the book Web site. This code is made simple and easy to understand by avoiding complex bookkeeping schemes while maintaining the essential features of the method. MATLAB was chosen as the example language because of its ubiquitous use in engineering studies and practice. This new edition includes the new MATLAB anonymous functions, which allow the programmer to embed functions into the program rather than storing them as separate files. Other changes include the addition of rational function interpolation in Chapter 3, the addition of Ridder's method in place of Brent's method in Chapter 4, and the addition of the downhill simplex method in place of the Fletcher–Reeves method of optimization in Chapter 10.

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NUMERICAL METHODS IN ENGINEERING

WITH MATLAB®

Second Edition

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Preface to the First Edition

This book is targeted primarily toward engineers and engineering students of advanced standing (sophomores, seniors, and graduate students). Familiarity with a computer language is required; knowledge of engineering mechanics (statics, dynamics, and mechanics of materials) is useful, but not essential.

The text places emphasis on numerical methods, not programming. Most engineers are not programmers, but problem solvers. They want to know what methods can be applied to a given problem, what their strengths and pitfalls are, and how to implement them. Engineers are not expected to write computer code for basic tasks from scratch; they are more likely to utilize functions and subroutines that have been already written and tested. Thus programming by engineers is largely confined to assembling existing bits of code into a coherent package that solves the problem at hand.

The "bit" of code is usually a function that implements a specific task. For the user the details of the code are of secondary importance. What matters is the interface (what goes in and what comes out) and an understanding of the method on which the algorithm is based. Since no numerical algorithm is infallible, the importance of understanding the underlying method cannot be overemphasized; it is, in fact, the rationale behind learning numerical methods.

This book attempts to conform to the views outlined above. Each numerical method is explained in detail and its shortcomings are pointed out. The examples that follow individual topics fall into two categories: hand computations that illustrate the inner workings of the method, and small programs that show how the computer code is utilized in solving a problem. Problems that require programming are marked with ■.

The material consists of the usual topics covered in an engineering course on numerical methods: solution of equations, interpolation and data fitting, numerical differentiation and integration, solution of ordinary differential equations, and eigenvalue problems. The choice of methods within each topic is tilted toward relevance to engineering problems. For example, there is an extensive discussion of symmetric, sparsely populated coefficient matrices in the solution of simultaneous equations.

In the same vein, the solution of eigenvalue problems concentrates on methods that efficiently extract specific eigenvalues from banded matrices.

An important criterion used in the selection of methods was clarity. Algorithms requiring overly complex bookkeeping were rejected regardless of their efficiency and robustness. This decision, which was taken with great reluctance, is in keeping with the intent to avoid emphasis on programming.

The selection of algorithms was also influenced by current practice. This disqualified several well-known historical methods that have been overtaken by more recent developments. For example, the secant method for finding roots of equations was omitted as having no advantages over Ridder's method. For the same reason, the multistep methods used to solve differential equations (e.g., Milne and Adams methods) were left out in favor of the adaptive Runge–Kutta and Bulirsch–Stoer methods.

Notably absent is a chapter on partial differential equations. It was felt that this topic is best treated by finite element or boundary element methods, which are outside the scope of this book. The finite difference model, which is commonly introduced in numerical methods texts, is just too impractical in handling curved boundaries.

As usual, the book contains more material than can be covered in a three-credit course. The topics that can be skipped without loss of continuity are tagged with an asterisk (*).

The programs listed in this book were tested with MATLAB® R2008b under Windows® XP.

Preface to the Second Edition

The second edition was largely precipitated by the introduction of *anonymous functions* into MATLAB. This feature, which allows us to embed functions in a program, rather than storing them in separate files, helps to alleviate the scourge of MATLAB programmers – proliferation of small files. In this edition, we have recoded all the example programs that could benefit from anonymous functions.

We also took the opportunity to make a few changes in the material covered:

- Rational function interpolation was added to Chapter 3.
- Brent's method of root finding in Chapter 4 was replaced by *Ridder's method*. The full-blown algorithm of Brent is a complicated procedure involving elaborate bookkeeping (a simplified version was presented in the first edition). Ridder's method is as robust and almost as efficient as Brent's method, but much easier to understand.
- The Fletcher–Reeves method of optimization was dropped in favor of the *downhill simplex method* in Chapter 10. Fletcher–Reeves is a first-order method that requires the knowledge of gradients of the merit function. Since there are few practical problems where the gradients are available, the method is of limited utility. The downhill simplex algorithm is a very robust (but slow) zero-order method that often works where faster methods fail.