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Book review

Scientific Computing with MATLAB

A. Quarteroni, F. Saleri, Springer-Verlag, Berlin, 2003, ISBN 3-540-44363-0

Scientific computing is a very broad subject. The contents of the book under review can be described using either one of the two titles: "A first course in numerical analysis" and "Advanced level programming of numerical methods with MATLAB". As implied by the two titles, the book can be used as the textbook of an introductory numerical analysis course for mathematics and computer science students, or students of various science and engineering fields with a strong mathematical background. As for the MATLAB contents, students who had previous exposure to MATLAB (perhaps in an introductory course) will be able to benefit more from the very advanced and sophisticated programming examples provided in the book. Those examples make the book appropriate as a reference book for programmers, scientists and engineers, who use MATLAB for solving numerical problems or need to program numerical methods. The book organization makes it suitable for self-study.

It is clearly written and easily understood.

Because of the wide scope of the book the readers can often benefit by using additional books for complementary information. In the following I will briefly review the contents of the various chapters of the book and provide some suggestions for complementary material from the viewpoint of someone who has been teaching engineering students numerical problem solving and MATLAB programming for many years.

The first chapter, which is entitled "What can't be ignored", contains preliminary and introductory material: real and complex numbers, floating point number operations, matrices and vectors, the zeros, the integration and the differentiation of real functions, polynomials, computational errors and computational cost of algorithms. This chapter also tackles the enormous task of trying to efficiently bridge between complete lack of knowledge about MATLAB and the ability to program a numerical algorithm with MATLAB. Even experienced MATLAB programmers can find some new tools and ideas in this chapter (as well as in the other chapters of the book). However, it appears that trying to bridge such a wide gap does create some inconsistencies and other potential problems. Thus, to students who did not have any exposure to programming before tackling this book some introduction to MATLAB programming is definitely recommended.

New MATLAB commands, statements and function names are displayed on the margin when they introduced the first time and the page where they are defined is also shown in the Index. Those features are very helpful when trying to understand the more complex MATLAB programs presented in the following chapters. Exercises are presented at the end of the chapter. It should be pointed out that detailed solutions are provided for all the exercises. The solved exercises are very helpful, especially for self-study.

The second chapter introduces numerical methods for solving nonlinear equations. The bisection method, the Newton method, and fixed-point iterations for one equation are presented and analyzed in detail. I would recommend complementing this material with solution techniques of systems of nonlinear equations, such as the multi-dimensional Newton and Broyden's quasi Newton methods (see, for example, pp. 359–366 in [1]). Those techniques, which required quite tedious programming using programming languages that do not support matrix operations can be programmed in a nice and compact form when using MATLAB.

The uses of the various techniques for solving nonlinear equations are demonstrated in detail using fairly simple examples, which can be easily defined as a MATLAB "inline" function. For science and engineering students solving some larger scale, realistic examples can be beneficial. When using MATLAB the com-

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plexity of the problem to be solved is not a concern, and there are many sources where practical problems that require numerical solution can be found (see, for example, [2,3]). This chapter (as all the other chapters) contains a section entitled "What we have not told you". In this section some of the functions provided by MATLAB for solving one nonlinear equation, systems of nonlinear equations and computing zeros of a polynomial are described briefly and some additional references are provided.

The subject of the 3rd chapter is approximation of functions and data, and it includes Lagrangian polynomial interpolation, Chebyshev interpolation, trigonometric interpolation and fast Fourier transform, piecewise linear interpolation, approximation by spline functions and the least squares method. Use of large scale examples together with some statistical analysis of the least squares regression results can nicely complement the material presented in this chapter.

Numerical differentiation and integration are discussed in Chapter 4. The forward, backward and centered finite difference formulas for approximation of the derivatives are discussed and analyzed as well as the midpoint, trapezoidal, Gauss, Simpson and the Simpson adaptive formulas for numerical integration. Advanced related topics such as the use of MATLAB provided functions for multidimensional integrals are mentioned in the "What we have not told you" section.

For solution of linear systems (Chapter 5) the LU factorization method with pivoting is discussed and analyzed. The Thomas algorithm and the Jacobi, Gauss-Seidel and the Richardson iterative methods are also described in detail. The associated MATLAB functions presented provide nice demonstration of the use of specific matrix operations and functions provided by MATLAB to yield compact codes for complex algorithms.

The 6th chapter is a short chapter, which presents the power method and some of its modifications for calculating a few of the eigenvalues of a matrix. For similarity transformation based methods (such as the QR method) the user is referred to the MATLAB function library and additional sources.

Solution of ordinary differential equations (initial value problems) is discussed in Chapter 7. The methods forward and backward Euler, Crank–Nicolson, 4th order Runge–Kutta and predictor–corrector methods are introduced and their stability and convergence is analyzed. It is recommended to complement the material of this chapter with information related to step-size control and stiff equations (see, for example, pp. 347–352 in Dahlquist et al. [4]).[1]

In Chapter 7 the finite difference and finite element approximation techniques for solving two point boundary value problems are presented, MATLAB functions for solving two particular problems are provided. Consistency and convergence analysis are carried out for the five point finite difference scheme.

While reviewing the book I came across some technical problems. In my opinion it is important to mention those problems as their correction can make the book even better. The authors can probably use their website (http://mox.polimi.it/Springer/) to inform the readers regarding most of the corrections. The specific comments related to technical errors follow.

(1) It seems that the MATLAB programs were retyped for inclusion in the book and there are some typographical errors. We retyped only a few of them and found that there is a missing parenthesis in the program on p. 31 and a missing parameter (varargin{:}) on p. 40. It is recommended to check all the printed programs for typographical errors.
(2) Some of the MATLAB commands used are not described and/or do not appear in the Index (see, for example, the commands *union* and *unique* on p. 98 and *ischar* on p. 125).
(3) The authors try to make the presentation of preliminary details of some MATLAB commands more interesting by including the commands in examples related to the subject matter already in the introductory chapter of the book. This may lead to some inconsistencies. For example, the first short MATLAB program, which contains algebraic and logical operators and a while-loop is presented on p. 4. However, the operators are defined only on p. 29 and the while-loop is defined on p. 30. This may be confusing to readers who do not have background in programming. A good reference of MATLAB preliminaries should be offered to such readers.

[1] A new (2003) edition of this book is available from Dover Publications.

(4) In case of programs, which depend on machine speed (or accuracy), the results can be very much different from what is presented in the book (see Example 1.4). In such cases adequate warning should be provided.
(5) More recent versions of MATLAB can also yield different results than those shown. In the extreme case, a particular command is not supported any more (*flops*, p. 109), or the results presented are different (*fzero*, p. 16).
(6) There are no comments whatsoever in the MATLAB programs (except the description of the input parameters of the functions). In my opinion, comments are important in order to understand the logic of the program, in particular when using MATLAB, where many of the convenient matrix manipulation commands can be quite difficult to understand.
(7) There are no x or y axes labels in any of the graphs. For me, as an engineer, graphs without labels are unacceptable.

In conclusion, I find this book very valuable as textbook in an introductory numerical analysis course and as a textbook for self-study for undergraduate and graduate students who want to extend their knowledge of numerical methods and MATLAB programming. The book is highly recommended also as a reference book to anyone who routinely uses MATLAB for numerical problem solving, or needs to program numerical methods.

References

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