PREFACE

MATLAB® is an abbreviation for MATrix LABoratory and it is ideally suited for computations involving matrices. Since all of the sciences routinely collect data in the form of (spreadsheet) matrices, MATLAB turns out to be particularly suitable for the analysis of mathematical problems in an assortment of fields. MATLAB is very easy to learn how to use and has tremendous graphical capabilities. Many schools have site licenses and student editions of the software are available at special affordable rates. MATLAB is perhaps the most commonly used mathematical software in the general scientific fields (from biology, physics, and engineering to fields like business and finance) and is used by numerous universities in mathematics departments.

This book is an undergraduate-level textbook giving a thorough introduction to the use of the MATLAB software with an emphasis on scientific computing. It is largely self-contained, with the prerequisite of a basic course in single-variable calculus and it covers many topics in numerical analysis. Numerous applications are given to an assortment of fields including linear algebra, probability, finance, ecology, and discrete mathematics.

MATERIAL

The book includes seven chapters, whose contents we now briefly summarize. Chapter 1 introduces the reader to some of MATLAB's basic functionality in a tutorial fashion. The important concept of a "while loop" is introduced rather early through a problem in finance (paying off a loan). Chapter 2 covers the basic notions of numerical analysis including approximations, errors, and relative errors. The problem of approximating a function using Taylor polynomials is used as a prototypical problem in numerical analysis. Taylor's theorem readily provides quality control (error bounds) on such approximations, and MATLAB will make it easy to see the effectiveness of such bounds. In Chapter 3, we introduce the reader to M-files, which are programs in MATLAB. Examples of M-files are created that highlight the distinctions between the two types of M-files, scripts and functions. MATLAB has many built-in M-files, and the final section for this chapter presents several that are particularly useful for (pre-)calculus-related tasks. Subsequently, in Chapter 4, we cover all of the logical features that are available for creating M-files. Through a series of interesting problems, this chapter introduces the reader to various strategies for writing effective programs. When MATLAB does computations, it needs to translate the numbers that the user inputs into computer numbers, and uses a corresponding floating point arithmetic to carry out the needed computations. Details of this process are covered in Chapter 5. One important topic in this chapter is the propagation of the roundoff errors, and

strategies on how to control them. The problem of finding a root of an equation goes back to antiquity. Chapter 6 begins with a historical introduction to this interesting problem, and then goes on to introduce several effective numerical schemes for rootfinding problems. M-files are constructed and practical experiments are conducted to test their relative effectiveness. The final section of Chapter 6 provides some important theory on these methods.

Chapter 7 covers matrices and linear systems, and is, by far, the longest chapter of the book. Since the basic structure in MATLAB is a matrix and it was originally conceived as a software for solving associated linear systems, there are many features that are presented. The chapter begins with an introduction to matrices and their arithmetic. Next, in Section 7.2, some beautiful applications of matrices to the generation of computer graphics are given. This section will show, among other things, how to create movies in MATLAB and how to create high-resolution graphics of complicated objects such as fractals. In Sections 7.3 and 7.4, the important problem of solving linear systems is introduced, and it is shown how to take advantage of MATLAB's built-in solvers. Included among the numerous applications of linear systems are polynomial interpolation problems, traffic logistics, input-output analysis, and combinatorics. In Section 7.5, the algorithm of Gaussian elimination is discussed in detail from a numerical and algorithmic perspective. Related topics such as complexity and LU decompositions are also included. Section 7.6 covers topics from numerical linear algebra concerning norms, error analysis and eigenvalues. In Section 7.7 we develop iterative methods. Codes are written for several of these methods and then they are compared along with their rates of convergence. Some interesting theory is also presented, as well as a detailed discussion on sparse matrices.

The book also includes two appendices. Appendix A gives a brief introduction to the use of MATLAB's Symbolic Toolbox, and Appendix B provides solutions to all of the Exercises for the Reader that are scattered throughout the text. The text is punctuated with numerous historical profiles (and photographs) of some of the scientists who have made significant contributions to the areas under investigation.

INTENDED AUDIENCE AND STYLE OF THIS BOOK

This book is written for students or professionals wishing to learn about either MATLAB or scientific computation. It is part of a larger book that the author has written (also published by John Wiley & Sons), entitled *Introduction to Numerical Ordinary and Partial Differential Equations Using MATLAB*. Explanations are written in a style that is rigorous yet user-friendly. We do not gloss over any needed details. Many illustrative examples are included throughout the text, and in addition, there are many "Exercises for the Reader" interspersed throughout the text that test the reader's understanding of the important concepts being introduced. Solutions to all of these Exercises for the Reader are included in an appendix. In addition, the individual sections conclude with extensive exercise sets, making this book suitable for use as a textbook. As a textbook, it could serve

either as a supplementary text to any math/science course wishing to make use of MATLAB (such as a numerical analysis or linear algebra course), or as a primary text for an introductory course in scientific computation. To facilitate readability of the text, we employ the following font conventions: Regular text is printed in the (current) Times New Roman font, MATLAB inputs and commands appear in `Courier New font`, whereas MATLAB output is printed in Ariel font. Key terms are set in **bold type**, while less essential vocabulary is set in *italics*.

Some sections are marked with an asterisk to indicate that they should be considered as optional; their deletion would cause no major disruption to the main themes of the text. Some of these optional sections are more theoretical than the others (e.g., Section 6.5: Error Analysis and Comparison of Rootfinding Methods), while others present applications in a particular related area (e.g., Section 7.2: Introduction to Computer Graphics and Animation). The programs and codes in the book have all been developed to work with the latest versions of MATLAB (Student Versions or Professional Versions).[1] All of the M-files developed in the text and the Exercises for the Reader can be downloaded from book's ftp site:

`ftp://ftp.wiley.com/public/sci_tech_med/numerical_preliminaries/`

Although it is essentially optional throughout the book, when convenient we occasionally use MATLAB's Symbolic Toolbox that comes with the Student Version (but is optional with the Professional Version).

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I have had many wonderful teachers throughout my life and I would like to express my appreciation to all of them, and make special mention of some of them. Firstly, back in middle school, I spent a year in a parochial school with a teacher, Sister Jarlath, who really had a tremendous impact in kindling my interest in mathematics; my experience with her led me to develop a newfound respect for education. Although sister Jarlath has passed, her kindness and caring for students

[1] Every code and M-file in this book has been tested on MATLAB versions 5, 6, and 7. The (very) rare instances where a version-specific issue arises are carefully explained. One added feature of later versions is the extended menu options that make many tasks easier than they used to be. A good example of this is the improvements in the MATLAB graphics window. Many features of a graph can be easily modified directly using (user-friendly) menu options. In older versions, such editing had to be done by entering the correct "handle graphics" commands into the MATLAB command window.

and the learning process will live on with me forever. It was her example that made me decide to become a mathematics professor as well as a teacher who cares. Several years later when I arrived in Ann Arbor, Michigan, for the mathematics PhD program, I had intended to complete my PhD in the area of abstract algebra, in which I was very well prepared and interested. During my first year, however, I was so enormously impressed and enlightened by the analysis courses that I needed to take, that I soon decided to change my area of focus to analysis. I would particularly like to thank my analysis professors Peter Duren, Fred Gehring, M. S. ("Ram") Ramanujan, and the late Allen Shields. Their cordial, rigorous, and elegant lectures replete with many historical asides were a most delightful experience.

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Last, but certainly not least, I have two more individuals to thank. My mother, Christa Stanoyevitch, has encouraged me throughout the project and has done a superb job proofreading the entire book. Her extreme conscientiousness and ample corrections and suggestions have significantly improved the readability of this book. I would like to also thank my friend Sandra Su-Chin Wu for assistance whenever I needed it with the many technical aspects of getting this book into a professional form. Inevitably, there will remain some typos and perhaps more serious mistakes. I take full responsibility for these and would be grateful to readers who could direct my attention to any such oversights.