

Preface

MATLAB[®]¹ is an interactive system for numerical computation. Numerical analyst Cleve Moler wrote the initial Fortran version of MATLAB in the late 1970s as a teaching aid. It became popular for both teaching and research and evolved into a commercial software package written in C. For many years now, MATLAB has been widely used in universities and industry.

MATLAB has several advantages over more traditional means of numerical computing (e.g., writing Fortran or C programs and calling numerical libraries).

- It allows quick and easy coding in a very high-level language.
- Data structures require minimal attention; in particular, arrays need not be declared before first use.
- An interactive interface allows rapid experimentation and easy debugging.
- High-quality graphics and visualization facilities are available.
- MATLAB programs are completely portable across a wide range of platforms.
- Toolboxes can be added to extend the system, giving, for example, specialized signal processing facilities and a symbolic manipulation capability.
- A wide range of user-contributed MATLAB programs is freely available on the Internet.

Furthermore, MATLAB is a modern programming language and problem-solving environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent language for teaching and a powerful tool for research and practical problem-solving. Being interpreted, MATLAB inevitably suffers some loss of efficiency compared with compiled languages, but built-in performance acceleration techniques (including some runtime compilation) reduce the inefficiencies and users have the possibility of calling code and libraries written in other languages.

This book has two purposes. First, it aims to give a lively introduction to the most popular features of MATLAB, covering all that most users will ever need to know. We assume no prior knowledge of MATLAB, but the reader is expected to be familiar with the basics of programming and with the use of the operating system under which MATLAB is being run. We describe how and why to use MATLAB functions but do not explain the mathematical theory and algorithms underlying them; instead, references are given to the appropriate literature.

The second purpose of the book is to provide a compact reference to MATLAB. The scope of MATLAB has grown dramatically as the package has been developed

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(see Table 0.1), and even experienced MATLAB users may be unaware of some of the functionality of the latest versions. Indeed, the PDF documentation for MATLAB runs to well over ten thousand pages. Hence we believe that there is a need for a manual that is wide-ranging yet concise. We hope that our approach of focusing on the most important features of MATLAB, combined with the book's logical organization and detailed index, will make *MATLAB Guide* a useful reference.

The book is intended to be used by students, researchers, and practitioners alike. Our philosophy is to teach by giving informative examples rather than to treat every function comprehensively. Full documentation is available in the MATLAB help system, which can be accessed from the Home tab of the MATLAB Toolstrip, by typing `doc` in the Command Window, or on the website of The Mathworks. The contents of the help system are also available as PDF files, accessible via “PDF Documentation” links in the help system. When we refer to “the help system” we mean any one of these sources.

Our treatment includes many “hidden” or easily overlooked features of MATLAB and we provide a wealth of useful tips, covering such topics as customizing graphics, coding style, code optimization, and debugging. However, we discuss only officially documented MATLAB features (undocumented features can change without warning and cannot be relied on).

The main subjects omitted are Graphical User Interface (GUI) tools, which can be useful as front-ends to MATLAB computations, and MEX files.

We have not included exercises; MATLAB is often taught in conjunction with particular subjects, and exercises are best tailored to the context.

We have been careful to show complete, undoctored MATLAB output and to test every piece of MATLAB code listed. The only editing we have done has been to omit some lines of output (to save space) and replace them by a line consisting of “. . .”.

MATLAB runs on several operating systems and we concentrate on features common to all. We do not describe how to install or run MATLAB, or how to customize it—the documentation should be consulted for this system-specific information.

A web page for the book can be found at <http://www.siam.org/books/ot150>. It includes links to all the codes used as examples in the book, errata, and links to various MATLAB-related web resources. It also includes the bibliography of the book as a BIBTEX bib file and in PDF form with embedded links.

What This Book Describes

This book describes MATLAB 9.1 (Release 2016b). If you are not sure which version of MATLAB you are using, type `ver` or `version` at the MATLAB prompt.

How This Book Is Organized

The book begins with a tutorial that provides a quick tour of MATLAB. The rest of the book is independent of the tutorial, so the tutorial can be skipped—for example, by readers already familiar with MATLAB.

The chapters are ordered so as to introduce topics in a logical fashion, with the minimum of forward references. A principal aim was to cover MATLAB programs and graphics as early as possible, subject to being able to provide meaningful examples. Later chapters contain material that is more advanced or less likely to be needed by the beginner.

Table 0.1. *Selected highlights of MATLAB releases.*

Year	Version	Notable features
1978	Classic	Original Fortran version.
1984	1	Rewritten in C.
1985	2	30% more commands and functions, typeset documentation.
1987	3	Faster interpreter, color graphics, high-resolution graphics printing.
1992	4	Sparse matrices, animation, visualization, user interface controls, debugger, Handle Graphics [®] ,* Microsoft Windows support.
1997	5	Profiler, object-oriented programming, multidimensional arrays, cell arrays, structures, more sparse linear algebra, new ordinary differential equation solvers, browser-based help.
2000	6, R12	MATLAB desktop including Help browser, matrix computations based on LAPACK with optimized BLAS, function handles, <code>eigs</code> interface to ARPACK, boundary-value problem and partial differential equation solvers, graphics object transparency, Java support.
2002	6.5, R13	Performance acceleration, more control in warning and error handling.
2004	7.0, R14	Mathematics on nondouble operands (single precision, integer), anonymous functions, nested functions, publishing an M-file to HTML, \LaTeX , etc., enhanced plot annotation.
2008	7.6, R2008a	Enhanced object-oriented programming capabilities.
2008	7.7, R2008b	Upgraded random number generators.
2012	8.0, R2012b	Redesigned desktop with Toolstrip, new help system.
2013	8.2, R2013b	<code>table</code> data type and <code>categorical</code> arrays.
2014	8.4, R2014b	Source control, updated graphics system, <code>datetime</code> arrays, <code>datastore</code> .
2015	8.6, R2015b	New execution engine, <code>graph</code> and <code>digraph</code> classes
2016	9.0, R2016a	Live Editor, performance testing framework
2016	9.1, R2016b	Local functions in scripts, string arrays, tall arrays, implicit expansion of arrays with dimensions of length 1.

* Handle Graphics is a registered trademark of The MathWorks, Inc.

Using the Book

Readers new to MATLAB should begin by working through the tutorial in Chapter 1. The tutorial gives a fast-paced overview of the capabilities of MATLAB, with all its topics being covered in greater detail in subsequent chapters. Although it is designed to be read sequentially, with most chapters building on material from earlier ones, the book can be read in a nonsequential fashion by following cross-references and making use of the index. It is difficult to do serious MATLAB computation without a knowledge of arithmetic, matrices, colon notation, operators, flow control, and program files, so Chapters 4–7 contain information essential for all users.

Appendix A lists our choice of the top 111 MATLAB functions—those that we think every MATLAB user should know about. The beginner may like to tick off these functions as they are learned, while intermediate users can pick out for study those functions with which they are not already familiar.

From time to time we make reference to the extensive MATLAB documentation. Reference information for a particular function, `fun`, can be obtained by typing `help fun` or `doc fun`, but sometimes we need to refer to a page in HTML documentation that is not directly accessible with a `doc` command. In this case we point to the precise page in question by specifying a command such as

```
web([docroot '/matlab/numeric-types.html'])
```

Here, `docroot` refers to the location of the documentation on the system in question, so this command should work on any MATLAB installation. Note that the quote symbol, `'`, which displays in this way in MATLAB and is typeset this way in all the MATLAB code in this book, is typed as the right or closing quote, `'`, on the keyboard.

What’s New in the Third Edition

This third edition of the book is 25 percent longer than the second edition (2005) and differs from it in several respects.

1. Many changes and new features introduced in MATLAB are incorporated.
2. All figures are now in color (they were monochrome in the second edition).
3. New “Asides”, highlighted in gray boxes, contain discussions on MATLAB-related topics, such as anonymous functions, reproducibility, and color maps.
4. Our continuing experience in using MATLAB for teaching and research has led to numerous improvements and additions—in particular, more examples.
5. The “Advanced Graphics” chapter (Chapter 17) (previously title “Handle Graphics”) has been rewritten to reflect the major update to the graphics system introduced in MATLAB 2014b.
6. A new chapter “Object-Oriented Programming” (Chapter 19) presents an introduction to object-oriented programming in MATLAB through two examples of classes.
7. The chapter “The Symbolic Math Toolbox” (Chapter 20) has been revised to reflect the use of MuPAD as the underlying symbolic engine (previously the engine was Maple), and the chapter has been extended.

8. A new chapter “Graphs” (Chapter 21) describes the new MATLAB classes `graph` and `digraph`, for representing and manipulating undirected graphs and directed graphs.
9. A new chapter “Large Data Sets” (Chapter 22) describes MATLAB features for handling data sets so large that they do not fit into the memory of the computer.
10. A new chapter “The Parallel Computing Toolbox” (Chapter 25) describes this toolbox, which exploits multicore processors, clusters, and graphics processing units (GPUs).
11. New sections have been added, including “Empty Matrices” (Section 5.4), “Matrix Properties” (Section 9.1), “Argument Checking and Parsing” (Section 10.6), “Fine Tuning the Display of Arrays” (Section 13.4), “Live Editor” (Section 16.7), “Unit Tests” (Section 16.10), “String Arrays” (Section 18.2), “Categorical Arrays” (Section 18.4), “Tables and Timetables” (Section 18.6), and “Timing Code” (Section 23.1), and many existing sections contain new or reorganized material.
12. Changes in MATLAB terminology have been incorporated. For example, the terms “program files” and “local functions” replace what were previously called “M-files” and “subfunctions”.

Future Versions of MATLAB

MATLAB will continue to evolve. New versions are released twice a year, denoted “R20xya” and “R20xyb”. It is a good habit to inspect the release notes of each new version in order to see what has changed. They can be found by typing `doc` then selecting MATLAB or one of its installed toolboxes and following the link. The release notes also give advanced notice of changes planned for the future, listed under “Functionality being removed or changed”, enabling you to avoid using functions or syntax that will become obsolete.

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