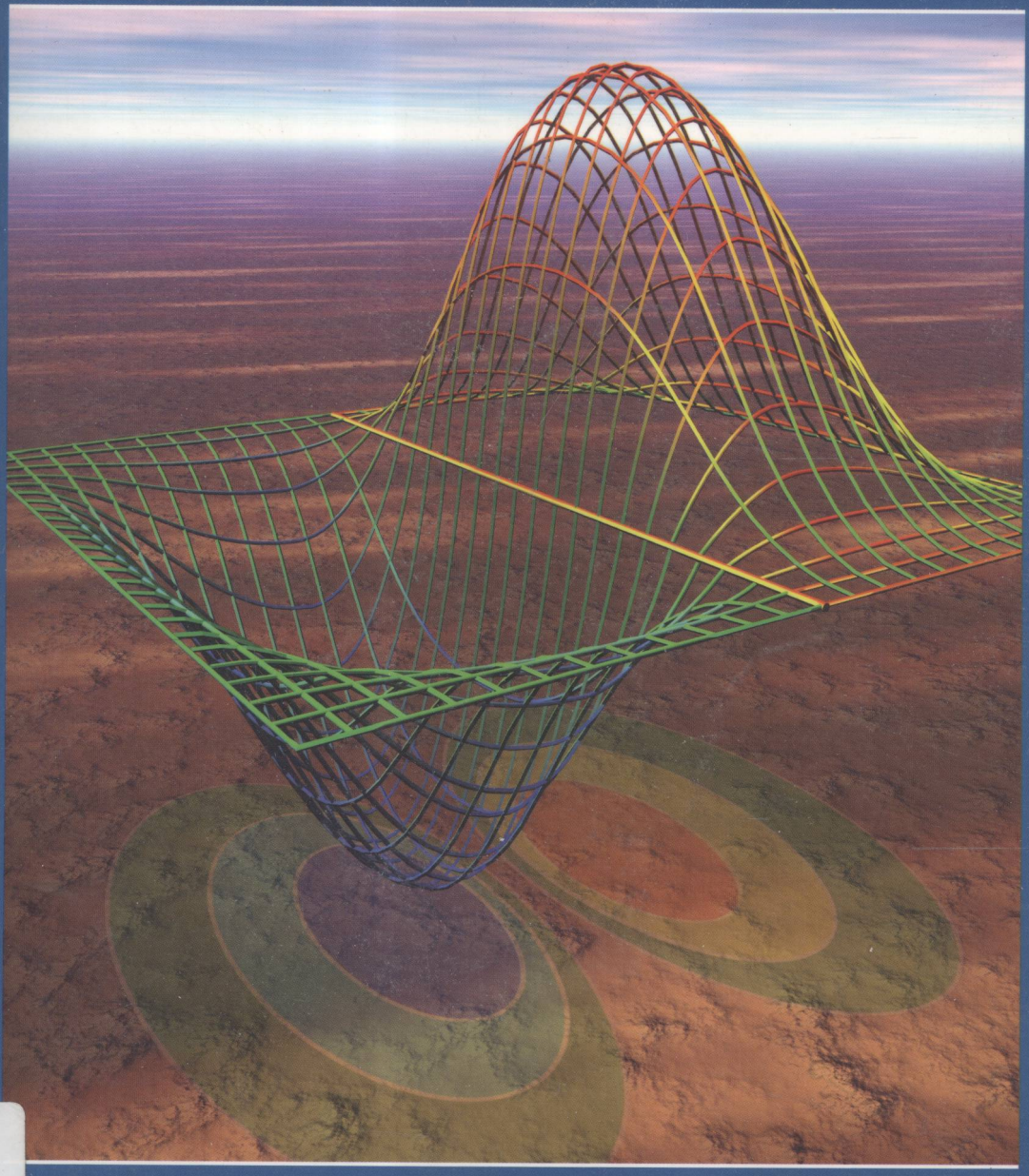
MATLAB®

An Introduction With Applications



Amos Gilat

Second Edition

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MATLAB®

An Introduction with Applications

Second Edition

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Amos Gilat

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Preface

MATLAB® is a very popular language for technical computing used by students, engineers, and scientists in universities, research institutes, and industries all over the world. The software is popular because it is powerful and easy to use. For university freshmen in it can be thought of as the next tool to use after the graphic calculator in high school.

This book was written following several years of teaching the software to freshmen in an introductory engineering course. The objective was to write a book that teaches the software in a friendly, non-intimidating fashion. Therefore, the book is written in simple and direct language. In many places bullets, rather than lengthy text, are being used to list facts and details that are related to a specific topic. The book includes numerous sample problems in mathematics, science, and engineering that are similar to problems encountered by new users of MATLAB.

This second edition of the book is updated for MATLAB 7. It includes also a new chapter (11) about symbolic math operations with MATLAB, and a new section in Chapter 4 that shows how to import and export data.

I would like to thank several of my colleagues at The Ohio State University. Professors Richard Freuler, Mark Walter, Brian Harper, and Walter Lampert, and Dr. Mike Parke for reading sections of the book and suggesting modifications. I also appreciate the involvement and support of Professors Robert Gustafson and John Demel and Dr. John Merrill from the First-Year Engineering Program at The Ohio State University. Special thanks to Professor Mike Lichtensteiger (OSU), and my daughter Tal Gilat (Stanford University), who carefully reviewed the entire book and provided valuable comments and criticisms.

I would like to express my appreciation to all those who have reviewed this text at its various stages of development, including Betty Barr, University of Houston; Andrei G. Chakhovskoi, University of California, Davis; Roger King, University of Toledo; Richard Kwor, University of Colorado at Colorado Springs; Larry Lagerstrom, University of California, Davis; Yueh-Jaw Lin, University of Akron; H. David Sheets, Canisius College; Geb Thomas, University of Iowa; Brian Vick, Virginia Polytechnic Institute and State University; Jay Weitzen, University of Massachusetts, Lowell; and Jane Patterson Fife, The Ohio State University. In addition, I would like to acknowledge the support of Joe Hayton, Ken Santor, Caroline Sieg, Katherine Hepburn, Simon Durkin, John Stout, and Jay Beck, all from John Wiley & Sons.

I hope that the book will be useful and will help the users of MATLAB to enjoy the software.

Amos Gilat
Columbus, Ohio
May, 2004

To my parents Schoschana and Haim Gelbwacks

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Introduction

MATLAB is a powerful language for technical computing. The name MATLAB stands for MATrix LABoratory, because its basic data element is a matrix (array). MATLAB can be used for math computations, modeling and simulations, data analysis and processing, visualization and graphics, and algorithm development.

MATLAB is widely used in universities and colleges in introductory and advanced courses in mathematics, science, and especially in engineering. In industry the software is used in research, development and design. The standard MATLAB program has tools (functions) that can be used to solve common problems. In addition, MATLAB has optional toolboxes that are a collection of specialized programs designed to solve specific types of problems. Examples include toolboxes for signal processing, symbolic calculations, and control systems.

Until recently, most of the users of MATLAB have been people who had previous knowledge of programming languages such as FORTRAN or C, and switched to MATLAB as the software became popular. Consequently, the majority of the literature that has been written about MATLAB assumes that the reader has knowledge of computer programming. Books about MATLAB often address advanced topics, or applications, that are specialized to a particular field. In the last few years, however, MATLAB is being introduced to college students as the first (and sometimes the only) computer program they learn. For these students there is a need for a book that teaches MATLAB assuming no prior experience in computer programming.

The Purpose of this Book

MATLAB: An Introduction with Applications is intended for students who are using MATLAB for the first time and have little or no experience in computer programming. It can be used as a textbook in freshmen engineering courses, or workshops where MATLAB is being taught. The book can also serve as a reference in more advanced science and engineering courses when MATLAB is used as a tool for solving problems. It also can be used for self study of MATLAB by students and practicing engineers. In addition, the book can be a supplement or a secondary book in courses where MATLAB is used, but the instructor does not have the time to cover it extensively.

Topics Covered

MATLAB is a huge program, therefore it is impossible to cover all of it in one book. This book focuses primarily on the foundations of MATLAB. It is believed

that once these foundations are well understood, the student will be able to learn advanced topics easily by using the information in the Help menu.

The order in which the topics are presented in this book was chosen carefully, based on several years of experience in teaching MATLAB in an introductory engineering course. The topics are presented in an order that allows the student to follow the book chapter after chapter. Every topic is presented completely in one place and then is used in the following chapters.

The first chapter describes the basic structure and features of MATLAB and how to use the program for simple arithmetic operations with scalars as with a calculator. The next two chapters are devoted to the topic of arrays. MATLAB's basic data element is an array that does not require dimensioning. This concept, which makes MATLAB a very powerful program, can be a little difficult to grasp for students that have only limited knowledge and experience with linear algebra and vector analysis. The book is written such that the concept of arrays is introduced gradually and then explained in extensive detail. Chapter 2 describes how to create arrays, and Chapter 3 covers mathematical operations with arrays.

Following the basics, script files are presented next in Chapter 4, followed by two-dimensional plotting in Chapter 5. The next topic covered, in Chapter 6, is function files, which is intentionally separated from the subject of script files. This has been proven to be easier to understand by students who are not familiar with similar concepts from other computer programs. Programming with MATLAB is covered in Chapter 7, which includes flow control with conditional statements and loops.

The next three chapters cover more advanced topics. Chapter 8 describes how MATLAB can be used for carrying out calculations with polynomials, and how to use MATLAB for curve fitting and interpolation. Plotting three-dimensional plots, which is an extension of the chapter on two-dimensional plots, is covered in Chapter 9. Chapter 10 covers applications of MATLAB for numerical analysis. It includes solving nonlinear equations, finding a minimum or a maximum of a function, numerical integration, and solution of first order ordinary differential equations. Chapter 11 is a new chapter that was added to the second edition of the book. It covers in great detail how to use MATLAB in symbolic operations.

The Framework of a Typical Chapter

In every chapter the topics are introduced gradually in an order that makes the concepts easy to understand. The use of MATLAB is demonstrated extensively within the text and by examples. Some of the longer examples in Chapters 1–3 are titled as tutorials. Every use of MATLAB is printed in the book with gray background. Additional explanations appear in boxed text with white background. The idea is that the reader will execute these demonstrations and tutorials in order to gain experience in using MATLAB. In addition, every chapter includes formal sample problems which are examples of applications of MATLAB for solving problems in math, science, and engineering. Each example includes a problem

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statement and a detailed solution. Some sample problems are presented in the middle of the chapter. All of the chapters (except Chapter 2) have a section at the end with several sample problems of applications. It should be pointed out that problems with MATLAB can be solved in many different ways. The solutions of the sample problems are written such that they are easy to follow. This means that in many cases the problem can be solved by writing a shorter, or sometimes "trickier," program. The students are encouraged to try to write their own solutions and compare the end results. At the end of each chapter there is a set of homework problems. They include general problems from math and science and problems from different disciplines of engineering.

Symbolic Calculations

MATLAB is essentially a software for numerical calculations. Symbolic math operations, however, can be executed if the Symbolic Math toolbox is installed. The Symbolic Math toolbox is included in the student version of the software and can be added to the standard program.

Software and Hardware

The MATLAB program, like most other software, is continually being developed and new versions are released frequently. This book covers MATLAB, Version 7, Release 14. It should be emphasized, however, that this book covers the basics of MATLAB which do not change that much from version to version. The book covers the use of MATLAB on computers that use the Windows operating system and almost everything is the same when MATLAB is used on other machines. The user is referred to the documentation of MATLAB for details on using MATLAB on other operating systems. It is assumed that the software is installed on the computer, and the user has basic knowledge of operating the computer.

The Order of Topics in the Book

It is probably impossible to write a textbook where all the subjects are presented in an order that is suitable for everyone. The order of topics in this book is such that the fundamentals of MATLAB are covered first (arrays and array operations), and, as mentioned before, every topic is covered completely in one location which makes the book easy to use as a reference. Some people, however, might want to follow a slightly different order, especially when the book is used as a text in a MATLAB class. For example, some teachers may cover the basics of script files (the first four sections of Chapter 4), before teaching Chapter 2 (creating arrays) and Chapter 3 (arrays operations). This will allow students to use script files instead of the Command Window when studying Chapters 2 and 3. Also, relational and logical operations (Section 7.1) and polynomials (Section 8.1) can be considered mathematical operations and presented together with the rest of the operations in Chapter 3.

Chapter 1
Starting with MATLAB

This chapter begins by describing the characteristics and purposes of the different windows in MATLAB. Next, the Command Window is introduced in detail and is the only one that is used in the rest of the chapter. Chapter 1 shows how to use MATLAB for arithmetic operations with scalars, similar to the way that a calculator is used. This includes the use of elementary math functions with scalars. The chapter then shows how to define scalar variables (the assignment operator) and how to use these variables in arithmetic calculations.

1.1 STARTING MATLAB, MATLAB WINDOWS

It is assumed that the software is installed on the computer, and that the user can start the program. Once the program starts, the window that opens, shown in Figure 1-1, contains three smaller windows which are the Command Window, the Current Directory Window, and the Command History Window. This is the default view of MATLAB. These windows are three of eight different windows in MATLAB. A list of the various windows and their purpose is given in Table 1-1. The **Start** button on the lower left side can be used to access MATLAB tools and features.

Four of the windows, the Command Window, the Figure Window, the Editor Window, and the Help Window, are used extensively throughout the book and are briefly described on the following page. More detailed descriptions are included in the chapters where they are used.

Command Window: The Command Window is MATLAB's main window, and opens when MATLAB is started. It is convenient to have the Command Window as the only visible window, and this can be done by either closing all the other windows (click on the **x** at the top right-hand side of the window you want to close), or by first selecting on the **Desktop Layout** in the **Desktop** manu, and then **Command Window Only** from the submenu that opens. How to work in the Command Window is described in detail in Section 1.2.

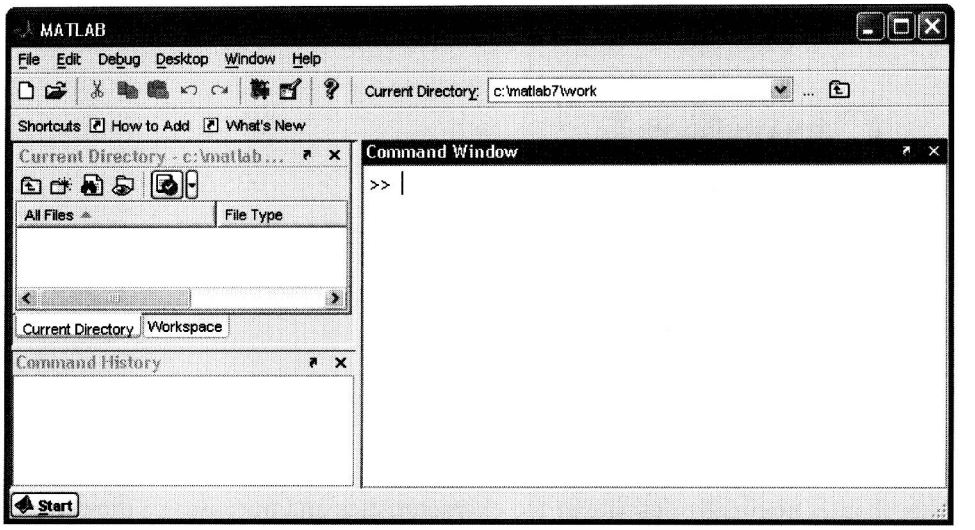

Figure 1-1: The default view of MATLAB desktop.

Table 1-1: MATLAB Windows

Window	Purpose
Command Window	Main window, enters variables, runs programs.
Figure Window	Contains output from graphic commands.
Editor Window	Creates and debugs script and function files.
Help Window	Provides help information.
Launch Pad Window	Provides access to tools, demos, and documentation.
Command History Window	Logs commands entered in the Command Window.
Workspace Window	Provides information about the variables that are used.
Current Directory Window	Shows the files in the current directory.

Figure Window: The Figure Window opens automatically when graphics commands are executed, and contains graphs created by these commands. An example of a Figure Window is shown in Figure 1-2. A more detailed description of this window is given in Chapter 5.

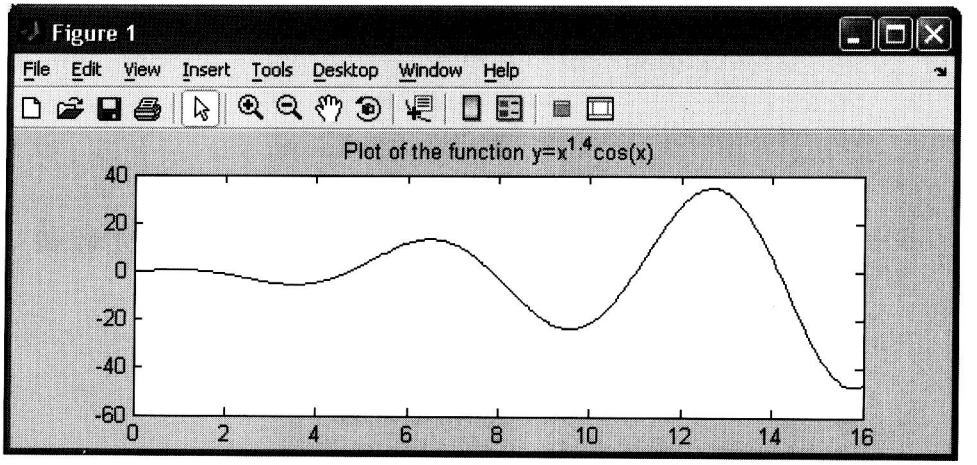

Figure 1-2: Example of a Figure Window.

Editor Window: The Editor Window is used for writing and editing programs. This window is opened from the **File** menu in the Command Window. An example of an Editor Window is shown in Figure 1-3. More details on the Editor Window are given in Chapter 4 where it is used for creating script files, and in Chapter 6 where it is used to create function files.

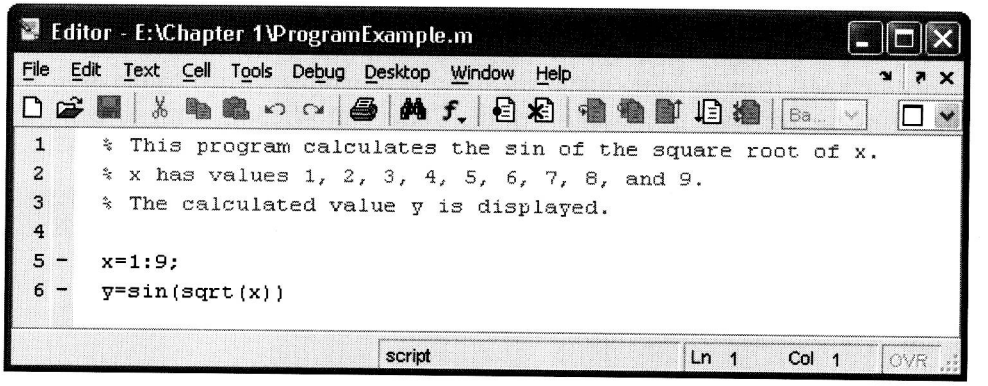

Figure 1-3: Example of an Editor Window.

Help Window: The Help Window contains help information. This window can be opened from the **Help** menu in the toolbar of any MATLAB window. The Help Window is interactive and can be used to obtain information on any feature of MATLAB. Figure 1-4 shows an open Help Window.

When MATLAB is started for the first time the screen looks like that shown in Figure 1-1 on page 6. For most beginners it is probably convenient to close all the windows except the Command Window. The closed windows can be reopened by selecting them from the **Desktop** menu. The windows shown in Figure 1-1 can be displayed by first selecting **Desktop Layout** in the **Desktop** menu and then **Default** from the submenu.

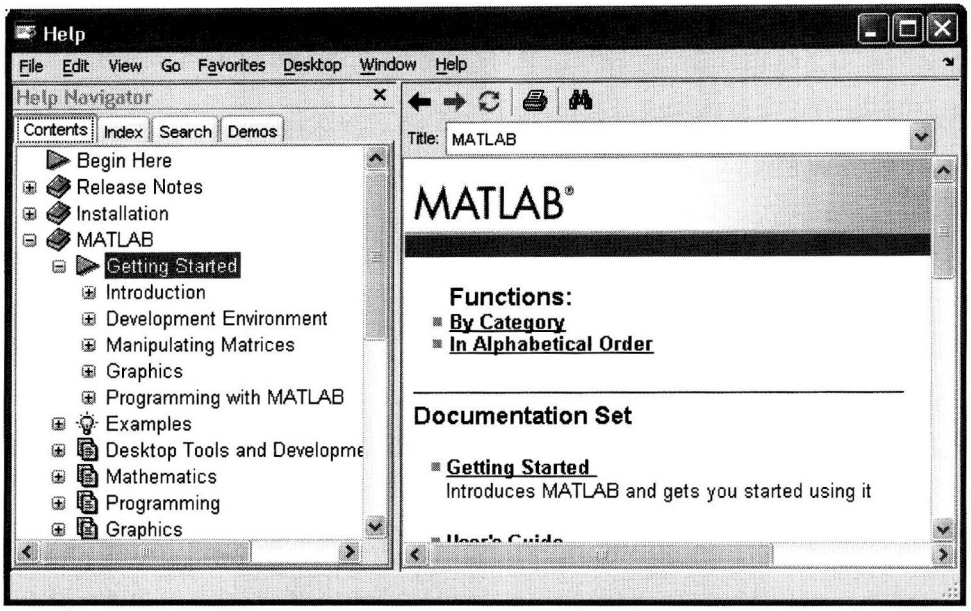

Figure 1-4: The Help Window.

1.2 *Working in the Command Window*

The Command Window is MATLAB's main window, and can be used for executing commands, opening other windows, running programs written by the user, and managing the software. An example of the Command Window, with several simple commands that will be explained later in this chapter, is shown in Figure 1-5.

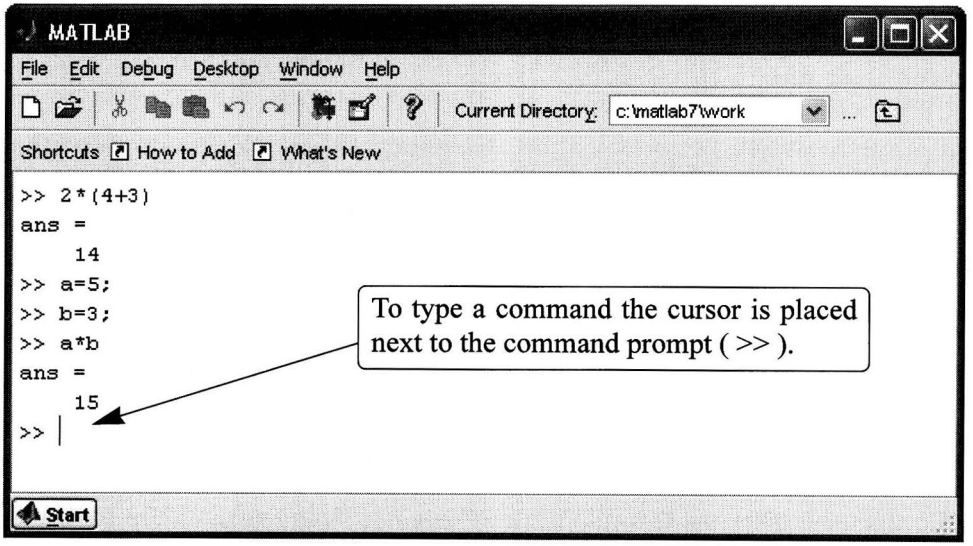

Figure 1-5: The Command Window.

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