

MATLAB

Introduction

*We cannot teach people anything.
We can only help them discover it within themselves.*
Galileo Galilei



What is MATLAB?

- **MATrix LABoratory**
- a *numerical computation and simulation tool*
 - developed into a commercial tool with a user friendly interface
- Not a computer algebra program (Maple, Mathematica), which performs *symbolic* operations.

MATLAB is designed to solve problems numerically, that is, in finite-precision arithmetic. Therefore it produces approximate rather than exact solutions. It is a tool designed for different tasks and is therefore not directly comparable.

 - Computer algebra functionality can be achieved with symbolic math toolbox.
- MATLAB, essentially involves a *single data structure: the array*.
 - All MATLAB variables are multidimensional *arrays*, no matter what type of data.
 - A *matrix* is a two-dimensional array (often used for linear algebra).

• Source: Introduction to MATLAB & SIMULINK: A Project Approach - M. Weeks



How to use MATLAB?

1. Interactive mode / Command line mode
 - type commands and use/define variables in command window
2. Program
 1. Simple scripts
 - M-file (name.m) with list of commands
 - Operate on existing data in workspace, or create new data
 - Variables remain in workspace (until cleared)
 2. M-file functions
 - M-file starting with `function` keyword
 - May return values
 - Easy to call from other functions (make sure file is in MATLAB search path)
3. Computational notebook
 - Use Live Editor

• Luke Dickens, Introduction to MATLAB Part 1, ICL



Main parts

1. Desktop tools and development environment
 - Mainly graphical user interfaces, editor, debugger, and workspace
2. Mathematical function library
 - Basic math functions such as sums, cosine, complex numbers
 - Advanced math functions such as matrix inversion, matrix eigenvalues, differential equations
3. The language
 - High-level language based on arrays, functions, input/output, and flow statements (for, if, while)

• Luke Dickens, Introduction to MATLAB Part 1, ICL



Main parts

4. Graphics
 - Data plotting in 2d and 3d,
 - Image analysis and animation tools
5. External interfaces
 - Interaction between MATLAB and other programming languages: C, FORTRAN, Python, ...



Goals

- MATLAB is an extensive piece of software, you will not be able to know all functions
 - MATLAB documentation: > 5000 pages
 - >300 built-in functions
 - >1000 M-files contained in the base product of MATLAB
- MATLAB is the SWISS ARMY KNIFE for numerical problems.
- MATLAB is a computing environment that is halfway between a programming language (where a user must do everything) and a menu-driven application (where the user only makes high level decisions). (*J. Burkardt*)

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MathWorks.com

MATLAB PRODUCT FAMILY	SIMULINK PRODUCT FAMILY	APPLICATIONS		
Parallel Computing Parallel Computing Toolbox MATLAB Parallel Server	Simulink System Composer Event-Based Modeling Stateflow SimEvents Physical Modeling Simscape Simscape Driveline Simscape Electrical Simscape Fluids Simscape Multibody Real-Time Simulation and Tooling Simulink Real-Time Simulink Desktop Real-Time Code Generation Simulink Coder Embedded Coder AUTOSAR Blockset Fixed-Point Designer Simulink PLC Coder Simulink Code Inspector DO Qualification Kit (for DO-178) IEC Certification Kit (for IEC 6032 and IEC 61508) HDL Coder HDL Verifier Filter Design HDL Coder Fixed-Point Designer GPU Coder Application Deployment Simulink Container MATLAB Compiler MATLAB Compiler SDK MATLAB Production Server MATLAB Web App Server Database Access and Reporting Database Toolbox MATLAB Report Designer	Signal Processing Signal Processing Toolbox Phased Array System Toolbox DSP System Toolbox Audio Toolbox Wavelet Toolbox Image Processing and Computer Vision Image Processing Toolbox Computer Vision Toolbox Lidar Toolbox Control Systems Control System Toolbox System Identification Toolbox Predictive Maintenance Toolbox Robust Control Toolbox Model Predictive Control Toolbox Fuzzy Logic Toolbox Simulink Control Design Simulink Design Optimization Reinforcement Learning Toolbox Motor Control Blockset Test and Measurement Data Acquisition Toolbox Instrument Control Toolbox Image Acquisition Toolbox OPC Toolbox Vehicle Network Toolbox ThingSpeak	RF and Mixed Signal Antenna Toolbox RF Toolbox RF Blockset Mixed-Signal Blockset SerDes Toolbox Wireless Communications Communications Toolbox WLAN Toolbox LTE Toolbox SD Toolbox Autonomous Systems Automated Driving Toolbox Robotics System Toolbox UAV Toolbox Navigation Toolbox ROS Toolbox Sensor Fusion and Tracking Toolbox RoadRunner RoadRunner Asset Library RoadRunner Scene Builder FDQA, ASIC, and SoC Development HDL Coder HDL Verifier Deep Learning HDL Toolbox Vision HDL Toolbox Filter Design HDL Coder Fixed-Point Designer SoC Blockset	Automotive Model-Based Calibration Toolbox Powertrain Blockset Vehicle Dynamics Blockset Automated Driving Toolbox IEC Certification Kit (for ISO 26262 and IEC 61508) Vehicle Network Toolbox AUTOSAR Blockset RoadRunner RoadRunner Asset Library RoadRunner Scene Builder Aerospace Aerospace Blockset Aerospace Toolbox UAV Toolbox DO Qualification Kit (for DO-178) Computational Finance Econometrics Toolbox Financial Toolbox Datafeed Toolbox Database Toolbox Spreadsheet Link (for Microsoft Excel) Financial Instruments Toolbox Trading Toolbox Risk Management Toolbox Computational Biology Bioinformatics Toolbox SimBiology Code Verification Polyspace Bug Finder Polyspace Bug Finder Access Polyspace Bug Finder Server Polyspace Code Prover Polyspace Code Prover Access Polyspace Code Prover Server Polyspace Products for Ada

<https://nl.mathworks.com/products.html>

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MATLAB Mobile
MATLAB Grader
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COMMUNITY AND THIRD-PARTY

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MATLAB and Simulink Books



History

LINPACK, EISPACK. (1970's)

- In the mid-1970s, Cleve Moler and several colleagues developed the FORTRAN subroutine libraries called LINPACK and EISPACK under a grant from the National Science Foundation.
- LINPACK was a collection of FORTRAN subroutines for solving linear equations, while EISPACK contained subroutines for solving eigenvalue problems.
- Together, LINPACK and EISPACK represented state of the art software for matrix computation.



Jack Dongarra, Cleve Moler, Pete Stewart, and Jim Bunch in 1978

```
C.... factor the A matrix
      CALL SGEFA(A, N, N, IPVT, INFO)
C.... copy B vector into X vector
      CALL SCOPY(N, B, 1, X, 1)
C.... solve the system of equations
      CALL SGESL(A, N, N, IPVT, X, 0)
```



History: MATLAB 0 (1978)

- Cleve Moler designed (as a "hobby" on his own time) it to give his students interactive access to LINPACK and EISPACK without having to learn FORTRAN
- Moler named his program MATLAB, for MATrix LABoratory.
- Over the next several years, when he would visit another university to give a talk, or as a visiting professor, he would end up by leaving a copy of his MATLAB on the university machines.
- Within a year or two, MATLAB started to catch on as a "cult" phenomena
- Check origins of MATLAB
<http://nl.mathworks.com/company/newsletters/articles/the-origins-of-matlab.html>
- Check 'evolution of MATLAB' on youtube
<http://www.youtube.com/watch?v=fa-sUaKv56A>





History: MATLAB 1 (1984)

- reprogrammed in C
- commercial potential
=> MathWorks
- 1983, John Little was exposed to MATLAB because of a visit Cleve made to Stanford.
- Little recognized the potential application of MATLAB to engineering applications.
- Little teamed up with Cleve Moler and Steve Bangert to develop a second generation, professional version of MATLAB written in C and integrated with graphics.
- The MathWorks, Inc. was founded in 1984 to market and continue development of MATLAB.



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History

- Software has evolved into an interactive system and programming language for general scientific and technical computation and visualization
- The MathWorks has become a commercial success.
 - In the period 1984 – 1991 the number of employees has doubled every year, from 2^0 people in 1984 to 2^7 people in 1991.
 - In the following years, the staff has increased roughly 20% per year, from 2^7 people in 1991, to 2^9 people in 1999, and 2^{10} people in 2002.
- **MATLAB 7 (2004)**
 - Release 14
- **MATLAB 2012b** – MATLAB 8.0
- MATLAB 2016a – MATLAB 9.0
- MATLAB 2022a – MATLAB 9.12

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MATLAB: pro

- Ease of use: interpreter and integrated environment
 - easy and fast coding
 - simple, compact, and procedural language with moderate learning curve
 - interactive code development proceeds incrementally
 - simple to learn and great for experimental research
 - ideal for prototyping
- Strong graphical and numerical capabilities
- Platform independent (but be careful)
- Lots of predefined functions (toolbox - Image Processing, Signal Processing, Financial, Symbolic Math ...)
- Extra functions can be created in M-files.
- Large user base with much user-contributed software
- Lots of code and information available on the web
- GUI: user can build its own gui



MATLAB: contra

- Interpreter can be slow, well written FORTRAN / C code can be sometimes faster
- Few data types/structures supported
- Restrictions on code portability (compile code and distribute – version dependent!)
- Not (yet) suitable for parallel programming
- Webb & Wilson, Dr. Dobb's Journal, (1999)
"Like every other scripting language, MATLAB began as a simple way to do powerful things, and it has become a not-so-simple way to do very powerful things."
- Cost licenses

















What about Excel?

- Spreadsheet programs are very good at dealing with table data in simple ways, and has graphics built-in
- More advanced calculations require programming in Visual Basic
- Advanced mathematics?
- Proprietary, binary file format
- Not available on all platforms



MATLAB is a Marketable Skill

- Check Job ad's
- Tiobe index:
<https://www.tiobe.com/tiobe-index/>

Aug 2022	Aug 2021	Change	Programming Language
1	2	▲	 Python
2	1	▼	 C
3	3		 Java
4	4		 C++
5	5		 C#
6	6		 Visual Basic
7	7		 JavaScript
8	9	▲	 Assembly language
9	10	▲	 SQL
10	8	▼	 PHP
11	16	▲	 Swift
12	12		 Classic Visual Basic
13	22	▲	 Delphi/Object Pascal
14	23	▲	 Objective-C
15	18	▲	 Go
16	14	▼	 R
17	17		 MATLAB
18	15	▼	 Ruby
19	13	▼	 Fortran
20	20		 Perl



Free MATLAB Alternatives

- GNU Octave (<https://www.gnu.org/software/octave/>) is a high-level language, that is mostly compatible with MATLAB.
- Scilab (<https://www.scilab.org/>) is a scientific software package for numerical computations providing a powerful open computing environment for engineering and scientific applications

Octave



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References

- Introduction to MATLAB® for Biologists
C.R. Webb, M. Domijan
Springer 2019
- Mastering MATLAB
Duane Hanselman
& Bruce Littlefield
Prentice Hall, 2012

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The ever-increasing number of books based on MathWorks products reflects the widespread use of these tools for research and development. The texts present theory, real-world examples, and exercises using MATLAB, Simulink, and other MathWorks products. They provide course materials for instructors in engineering, science, finance, and mathematics, and serve as authoritative references for researchers in academia and industry.

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- Use the MathWorks website:
 - MATLAB getting started
<https://nl.mathworks.com/help/matlab/getting-started-with-matlab.html>
 - <https://nl.mathworks.com/matlabcentral/>
 - highly active and contains moderated Q&A sections.
 - the community is in general helpful and receptive both to basic and advanced topics.
 - <https://blogs.mathworks.com/>
- Some useful advice from long-time MATLAB users:
 - [The best way\(s\) to learn MATLAB](#)
 - [Best practices for working in MATLAB for intermediate-to-advanced users](#)

Google is your friend

