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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. Therefor 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

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

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History

LINPACK, EISPACK. (1970's)

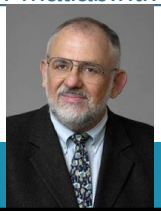
- In the mid-1970s, Cleve Moler and several colleagues developed the FORTRAN subroutine libraries called LINPACK and EISPACK under a grant from the National Science Foundation.
- LINPACK was a collection of FORTRAN subroutines for solving linear equations, while EISPACK contained subroutines for solving 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)
```

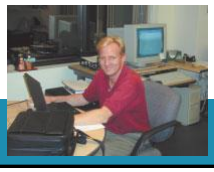

History: MATLAB 0 (1978)

- 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)

- *re*programmed 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.



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 $2^{\wedge 0}$ people in 1984 to $2^{\wedge 7}$ people in 1991.
  - In the following years, the staff has increased roughly 20% per year, from $2^{\wedge 7}$ people in 1991, to $2^{\wedge 9}$ people in 1999, and $2^{\wedge 10}$ people in 2002.
- **MATLAB 7** (2004)
  - Release 14
- **MATLAB 2012b** – MATLAB 8.0
- MATLAB 2016a – MATLAB 9.0
- MATLAB 2022a – MATLAB 9.12

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

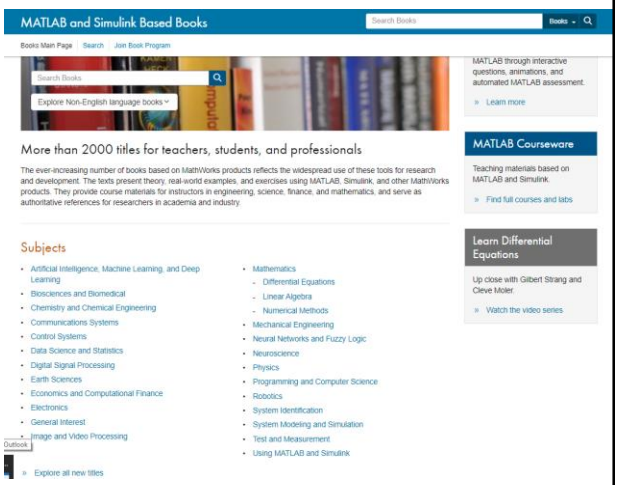
Free MATLAB Alternatives

- 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

References

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



How to Learn MATLAB

- 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