Lecture 1: MATLAB in a Nutshell

A8B17CAS

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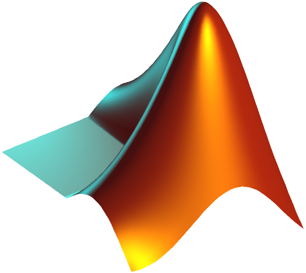
Outline

1. What is MATLAB?
2. Launching and Termination
3. MATLAB Environment
4. Scalars, Vectors, Matrices
5. Basic Math Operations



MATLAB is. . .

- High-level programming language (*4th generation language*).
- Interpreted language (not compiled, but. . . JIT).
  - Intended mainly for numerical computing (nevertheless includes MuPAD symbolic kernel).
- Philosophy: kernel & tool boxes & user-defined functions → wide application.
  - Wide possibilities of linking with other tools (Java, C++, Fortran, Python, .NET, Excel, physical- / multi-physical softwares).
- Speed (of well written) algorithm comes near to that of C++.
- Excellent for "fast prototyping."
  - MATLAB does not require variables declaration (not always the advantage).
- Multi-licensed for CTU.
  - Available for students as well!

    - CTU students: download.cvut.cz

    - FEE students: svti.fel.cvut.cz/cz/services/software/matlab.html

Historical Development of MATLAB

- the 1970's
  - Cleve Moler[1], MATLAB used instead of Fortran.
  - MATrix LABoratory → matrix is the basic data structure.
  - Fortran-based syntax.
- 1983
  - Jack Little rewrote Matlab in C.
  - New functionality and new mathematical libraries added.
- 1984 (MATLAB is so far for free!)
  - MathWorks founded in 1984
- 2004
  - Matlab used by more than 1 million of active users.
- now...
  - R2022a is the newest version of Matlab.
  - local distribution: Humusoft s.r.o.

[1] see: http://www.mathworks.com/company/aboutus/founders/clevemoler.html

Alternatives to Matlab

Fortran: most of the libraries still in Fortran, used mostly by physicists

Python: for free, fast and intuitive; Spyder provides Matlab-like features

Mathematica: symbolic and numerical calculations, excellent symbolic kernel, extensive applicability, mostly for mathematicians and physicists

Maple: symbolic and numerical calculations

MathCad: used for symbolic and numerical calculations, slightly out-of-date

Octave: for free, syntax and functionality similar to Matlab, not so extensive, smartphone executable

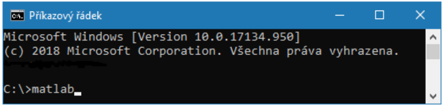
R: for free, designed particularly for statistical applications

Scilab: Matlab-like, open documentation

Derive: small, fast, Casio calculator executable

Launching MATLAB

- Desktop icon
- Command line:
  - `matlab`



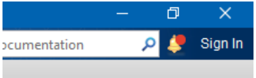
```
Microsoft Windows [Version 10.0.17134.950]
(c) 2018 Microsoft Corporation. Všechna práva vyhrazena.
[redacted]

C:\>matlab_
```

- MATLAB can be launched with a set of optional parameters.
  - `matlab -r "test(10)"`
- System requirements[2] for MATLAB R2022a+:
  - Windows 10+
  - 4 GB RAM
  - 3.1 GB of HDD (MATLAB only), 5-8 GB for a typical installation
  - Any Intel or AMD x86-64 processor
- Available also for Mac and Linux!

[2] https://www.mathworks.com/support/requirements/matlab-system-requirements.html

MATLAB Termination

- Close button in the top right of MATLAB window.



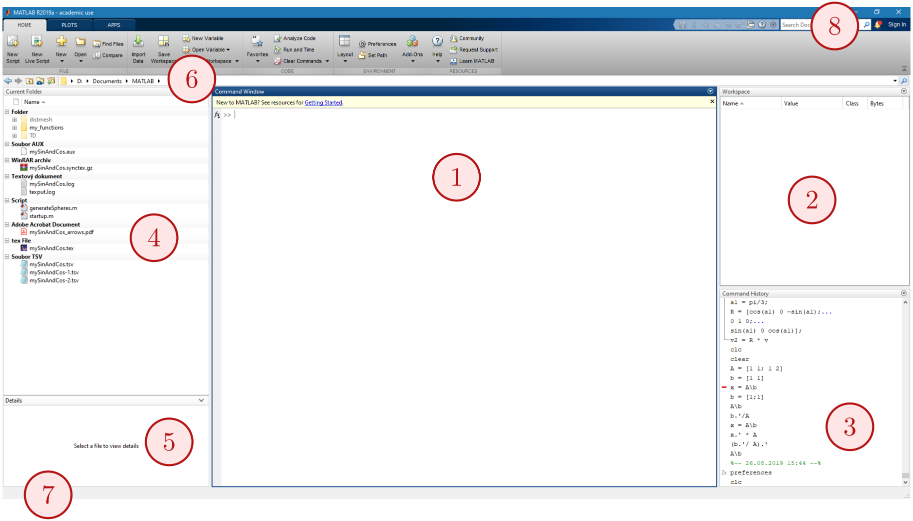
- Possibility to terminate MATLAB in the command window.

```
>> quit % terminates Matlab
>> exit %    -//-
```

- More advanced options (see documentation).

```
>> quit cancel
>> exit force
```

The MATLAB Environment



New to MATLAB? See resources for Getting Started.

```
fx >>
```

Current Folder

Name

- Folder
  - distmesh
  - my_functions
  - TD
- Soubor AUX
  - mySinAndCos.aux
- WinRAR archiv
  - mySinAndCos.synctex.gz
- Textový dokument
  - mySinAndCos.log
  - texput.log
- Script
  - generateSpheres.m
  - startup.m
- Adobe Acrobat Document
  - mySinAndCos_arrows.pdf
- tex File
  - mySinAndCos.tex
- Soubor TSV
  - mySinAndCos.tsv
  - mySinAndCos-1.tsv
  - mySinAndCos-2.tsv

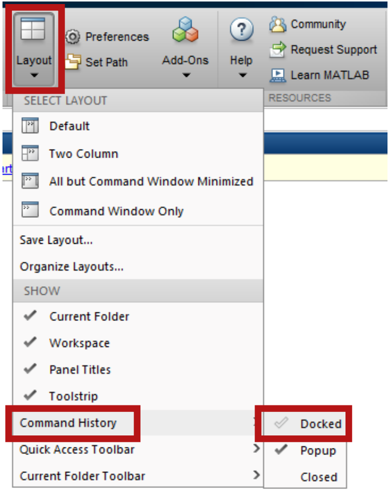
Select a file to view details

Command History

```
   al = pi/3;
   R = [cos(al) 0 -sin(al);...
   0 1 0;...
   sin(al) 0 cos(al)];
   v2 = R * v
   clc
   clear
   A = [1 1; 1 2]
   b = [1 1]
-  x = A\b
   b = [1;1]
   A\b
   b.'/A
   x = A\b
   x.' * A
   (b.'/ A).'
   A\b
   %-- 26.08.2019 15:44 --%
2x preferences
   clc
```

The Matlab Environment – Panels

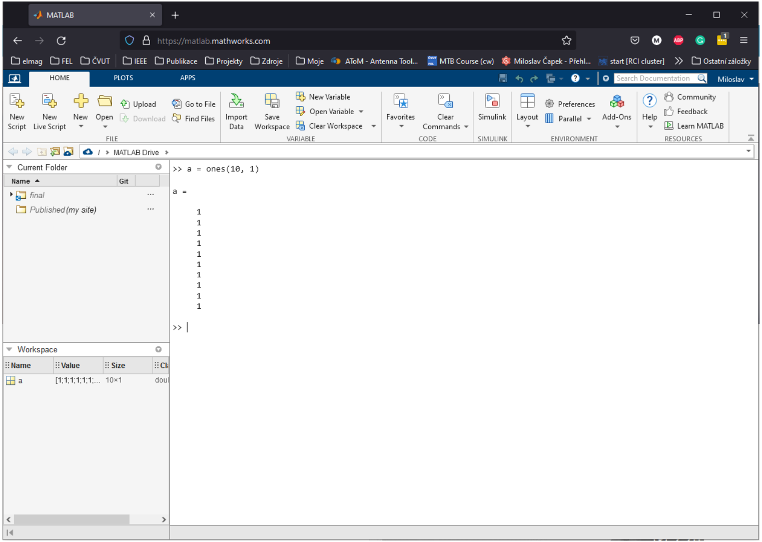
1. Command Window
2. Workspace
3. Command History – *not activated, to activate* →
4. Current Folder
5. Current Folder – Details
6. Current Working Directory
7. Status (“Busy” when Matlab is executing your code)
8. Search in documentation



MATLAB Online

- `matlab.mathworks.com`

- Runs in a web browser.
- Requires (CTU) log in.
- Slower than regular MATLAB.



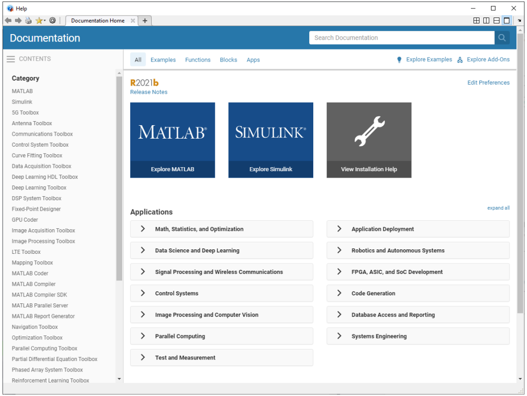
```
>> a = ones(10, 1)

a =

     1
     1
     1
     1
     1
     1
     1
     1
     1
     1

>> |
```

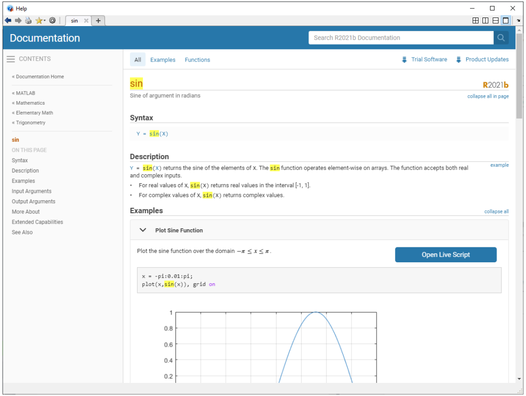
Name	Value	Size	Cl
a	[1;1;1;1;1;1;...	10×1	doul

Documentation

```
>> doc % opens documentation window
```

```
>> doc sin % opens documentation of sin function
```





sin

Sine of argument in radians

Syntax

```
Y = sin(X)
```

Description

Y = sin(X) returns the sine of the elements of X. The sin function operates element-wise on arrays. The function accepts both real and complex inputs.

- For real values of X, sin(X) returns real values in the interval [-1, 1].
- For complex values of X, sin(X) returns complex values.

Examples

Plot Sine Function

Plot the sine function over the domain $-\pi \le x \le \pi$.

```
x = -pi:0.01:pi;
plot(x,sin(x)), grid on
```

Matlab Commands

Matlab is cAsE sEnSiTiVe!

- Almost entirely, with certain exceptions (properties of graphics objects, ...).
- Pay attention to typos and variable names (see later).
  - New versions of Matlab offer certain options.

```
a, A, b, c, x1, x2, M_12, test1, matrix_A, fx, fX
```

- Beware of different syntax in Mathematica, *e.g.*, `sin(x)` vs. `Sin[x]`, etc.
  - Following syntax is incorrect both in Matlab and Mathematica:

```
matrix A % contains space
coef.a   % possible only if coef is of type 'struct'
```

  - Will be discussed in the next lectures.

Naming Conventions

- Choose names corresponding to the meaning of each particular variable.
  - Letters and numbers are allowed, other symbols (colon “:”, hyphen “-” and others) are not.
  - Underscore is allowed in the variable name “_” (not at the beginning, though!).

Naming Conventions

- Choose names corresponding to the meaning of each particular variable.
  - Letters and numbers are allowed, other symbols (colon ":", hyphen "-" and others) are not.
  - Underscore is allowed in the variable name "_" (not at the beginning, though!).

Recommendations:

- Lowercase letters in the names of scalars and variables (`a = 17.59;`).
- Matrix names usually start with a capital letter (`A = [ .. ];`).
- Iteration variables, variables used in `for` cycles usually named `m`, `n`, `k`, etc.
  - It is advisable to avoid `i` and `j` (complex unit).
- Avoid, if possible, standalone letter "`l`" (to be confused with one "`1`") and predefined variables in MATLAB environment (see later).
- Avoid using names of existing functions or scripts (overloading can occur).
- The same conventions are valid for names of functions and scripts.

Variable Names

- Examples of valid variable names:

```
a, A, b, c, x1, x2, M_12, test1, matrix_A, fx, fX
```

- Examples of invalid variable names:

```
1var     % starts with a number (not possible in MATLAB)
matrix A % contains space
coef.a   % possible only if coef is of type 'struct'
Test-1   % algebraic expressing: ans = Test - 1
f(y)      % makes sense when using symbolic expressions
```

- Examples of valid numbers in MATLAB,

```
3, -66, +0.0015, .015, 1e2, 1.6025e-10, 05.1
```

Workspace – Output Deletion

- To clean (erase) command window:

```
>> clc
```

- To clean one (or more) variable(s):

```
>> clear       % whole Workspace is deleted
>> clear XX    % variable XX is deleted
>> clear XX YY % variables XX and YY are deleted
>> clear z*    % everything starting with 'z' is deleted
```

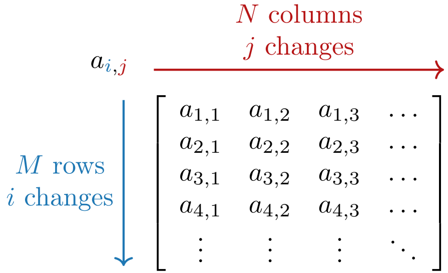
- `clear` has a number of other options (graphics, I/O)

Command History Window

- Command History window stores all commands from the Command Window.
- Command History is accessible though ↑ or ↓.
- it is possible to filter out past commands by, *e.g.*:
  » `A = [` + ↑.
- It is possible to copy-and-paste entire Command History:
  SHIFT / CTRL / CTRL + A → CTRL + C.

Matrices in MATLAB

- Matrix is a basic data structure in MATLAB.
- There are the following variables' types depending on size:
  - scalar: 1×1
  - vector: $M \times 1$ or $1 \times N$
  - matrix: $M \times N$
  - array (multidimensional matrices): $M \times N \times P \times Q \times R \times \dots$
- Matrices can be complex.
- It can contain text as well (beware of the length).
- M-by-N matrix:



N columns

j changes

$a_{i,j}$

M rows

i changes

$$\begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} & \cdots \\ a_{2,1} & a_{2,2} & a_{2,3} & \cdots \\ a_{3,1} & a_{3,2} & a_{3,3} & \cdots \\ a_{4,1} & a_{4,2} & a_{4,3} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

Matrix Creation

- Following techniques are available:
  - element-by-element entering (suitable for small matrices only),
  - colon notation ":" to define elements of series,
  - generation by built-in functions,
  - generation of matrices in m-files,
  - import and export from/to external files(`.mat`, `.txt`, `.xls`, ...).

Matrix Construction Element-by-element I.

- Test the following commands to construct matrices by element enumeration.

```
>> a1 = -1
>> a2 = [-1] % brackets are redundant
```

```
>> v1 = [-1 0 1]
>> v2 = [-1; 0; 1]
```

```
>> M1 = [-1 0 1; -2 0 2]
>> M2 = [-1 -2; 0 0 ; 1 2]
>> M3 = [[-1 -2]; [0 0]] % inner brackets are redundant
```

- Suitable for small matrices only.

$$a_1 = a_2 = -1$$

$$\mathbf{v}_1 = \begin{bmatrix} -1 & 0 & 1 \end{bmatrix}$$

$$\mathbf{v}_2 = \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}$$

$$\mathbf{M}_1 = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \end{bmatrix}$$

$$\mathbf{M}_2 = \begin{bmatrix} -1 & -2 \\ 0 & 0 \\ 1 & 2 \end{bmatrix}$$

$$\mathbf{M}_3 = \begin{bmatrix} -1 & -2 \\ 0 & 0 \end{bmatrix}$$

Matrix Construction Element-by-element II.

- Construct the following matrices:
  - Matrix values are defined inside square brackets `[]`,
  - semicolon “;” separates individual rows of a matrix.

$$\mathbf{A} = \begin{bmatrix} -1 & 1 \\ 1 & -2 \end{bmatrix} \qquad \mathbf{B} = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

Exercise

Matrix Construction

- Semicolon placed at the end of a command suppresses the display of the output in the Command Window.
  - Note: it is possible to copy and paste code including “»”

```
>> a = 1
>> b = 5;
```

- When there is more than one command on the same line, a comma is used to separate them.

```
>> a = 1, b = 5
>> a = 1; b = 5;
```

- Row vs. column vector:

```
>> c = [1 0 0]
>> d = [0; 0; 1]
```

Basic Math Operators I.

- Operator types:
  - arithmetic:
    - matrix,
    - vector,
  - relational,
  - logical and other (to be mentioned later ...).
- Other operations using MATLAB functions:
  - complex conjugate,
  - sum, determinant, square root,
  - and hundreds of other functions ...

+	addition
−	subtraction
*	multiplication
^	power
.'	transpose
\	left matrix division
/	right matrix division
.	dot notation

Notice the operator's precedence (to be discussed later).

- see MATLAB → Language Fundamentals → Operators and Elementary Operations → Arithmetic

Basic Math Operators II.

Type in the following commands:

- Zero can be omitted with a decimal number beginning with zero (not recommended).

```
>> a3 = -2/4
>> a4 = -0.5
>> a5 = -.5
```

- What is the difference between a_3, a_4 and a_5?
- Beware the precedence of operators:

```
>> 3*5*6
>> a1 = 15
>> a2 = 10;
>> a2/a3
>> a2/a3*a4
>> a2/(a3*a4)
```

- Explain the difference between `a2/a3*a4` and `a2/(a3/a4)`.

Exercise

Basic Math Functions I.

Math functions in MATLAB are generally divided in three groups:

- Scalar
  - Function operates over individual elements of a matrix,
  - *e.g.*: `sin`, `sqrt`, `log`, `factorial`.
- Vector
  - Function operates over individual rows/columns of a matrix,
  - *e.g.*: `sum`, `max`.
- Matrix
  - Function operates over a whole matrix,
  - *e.g.*: `det`, `trace`.

Basic Math Functions II.

- Using MATLAB help, calculate the following expression: $a\sin^2(\alpha) + a\cos^2(\alpha) - a$
  - Use numerical values your own choice.
- Verify following logarithmic identity: $\log_{10}(a) + \log_{10}(b) - \log_{10}(ab) = 0$
- Find sum of all elements in individual rows of the following matrix:

$$T = \begin{bmatrix} \frac{1}{2} & \frac{1}{3} & \frac{1}{4} & \frac{1}{5} \\ 6 & 7 & 8 & 9 \\ 0.2 & 0.3 & 0.4 & 0.5 \end{bmatrix}$$

Exercise

Basic Math Functions III.

- Assume following vectors $\mathbf{u} = (1, 2, 3)$ and $\mathbf{v} = (3, 2, 1)$.
  - Calculate:

$$\begin{array}{cc} \mathbf{u}\mathbf{v}^{\mathrm{T}} & \mathbf{v}\mathbf{u}^{\mathrm{T}} \\ \mathbf{v}^{\mathrm{T}}\mathbf{u} & \mathbf{u}^{\mathrm{T}}\mathbf{v} \\ \mathbf{u} \cdot \mathbf{v} & \mathbf{u} \times \mathbf{v} \end{array}$$

  - Following functions are needed:
    - `transpose` (`.'`) of a matrix,
    - `dot` scalar product,
    - `cross` product.
  - What is the result of the above mentioned operations?

$$\mathbf{A} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

$$\mathbf{A}^{\mathrm{T}} = \begin{bmatrix} 1 & 3 & 5 \\ 2 & 4 & 6 \end{bmatrix}$$

Exercise

Questions?

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