

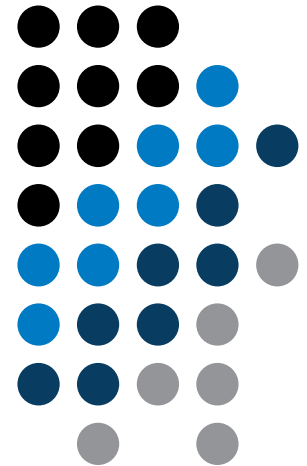
A0B17MTB – Matlab

# Introduction



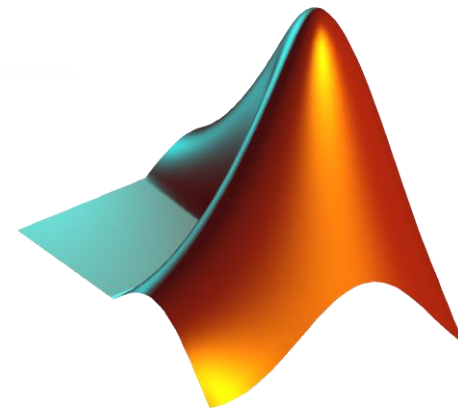
Miloslav Čapek  
miloslav.capek@fel.cvut.cz  
Filip Kozák, Viktor Adler, Pavel Valtr

Department of Electromagnetic Field  
B2-626, Prague



# You will learn ...

---



**What is MATLAB?**

**Why to learn MATLAB?**

**Details of the A0B17MTB course**

**Recommended literature, further resources**

**First steps in MATLAB**

# What is MATLAB?



# MATLAB is...

- high-level programming language (*4th gener. 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-license for CTU
  - Available for students as well!
  - [download.cvut.cz](http://download.cvut.cz) - CTU students
  - <https://matlab-lic2.feld.cvut.cz/> - FEE students

# Why to learn MATLAB?

- Matlab is a worldwide standard
- used by more than 5000+ universities worldwide
- licenses used by thousands of corporations in aviation, biotechnology, electronics, cybernetics, mechanical engineering, finance, ...
- knowledge of Matlab can be used in other courses at the University as well as in professional life

# Where to make use of Matlab?

- data processing and visualization during laboratory exercises
- when elaborating diploma works
- seminar exercises (signals, algorithm development, ...)
- theory verification (mathematics and physics classes, electromagnetic field, electronic circuits, ...)
  
- studying abroad (Erasmus, Sokrates)

⇒ **“everywhere”** :)

# Historical development of MATLAB

- 70's
  - Cleve Moler, Matlab used instead of Fortran
  - MATriX LABoratory → matrix is the basic data structure
  - Fortran-based syntax
- 1983
  - Jack Little rewriting Matlab in C
  - new functionality and new mathematical libraries added
- 1984 (Matlab is so far for free!)
  - MathWorks founded in 1984
  - <http://www.mathworks.com/>
- 2004
  - Matlab used by more than 1 million of active users
- now...
  - ... R2016b is the newest version of Matlab
  - local distribution: Humusoft s.r.o.

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



# Alternatives to MATLAB

- Matlab vs. C/C++
  - optimal language strongly depends on the application
  - C/C++ faster in general, Matlab, on the other hand, provides implicit parallelism
  - general principle: Matlab more than suitable for everything except commercial compiled code (especially Matlab 6.5 and above: JIT + Real-Time Type Analysis)
- Matlab vs. Fortran
  - Matlab has wider support, more intuitive syntax
  - speed of a well written code is (usually, at least) comparable
  - utilization of Fortran is on the decline
- Matlab vs. Python
  - Matlab offers significant support thanks to MathWorks, Matlab File Exchange
  - Python entirely for free, it's becoming more and more popular

# A0B17MTB

- 13 weeks (14<sup>th</sup> week is a ‘reserve’)
  - 11 blocks with new theory, 1 block of bonuses, 1 block of examples
- **conditions of credit award:**
  - to hand in a project (next-to-last week of the semester, **60 points**)
    - **competition assignment** (see next slide)
  - to pass a test, **20 points** (min. 50%, next-to-last week)
    - on top of that two short tests during semester, **20 points** (min. 10 points are needed)
    - 3 bonus examples during the semester, **5 bonus points**
  - max. 2 missed classes (more absences only after prior arrangement)
    - any lecture can be substituted
- could happen that not all of the stuff of the course will be presented, because of time constraint – understanding the basics is a priority
  - bonus stuff (slides) available for advanced students
- <https://cw.fel.cvut.cz/wiki/courses/a0b17mtb/start>

Data types

Code execution

Visualization

Relation and logical operators

Matrix operations

User scripts and functions

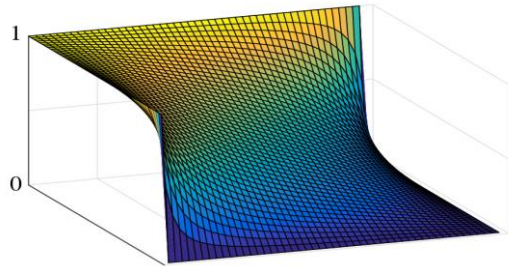
Numerical methods

Symbolic math

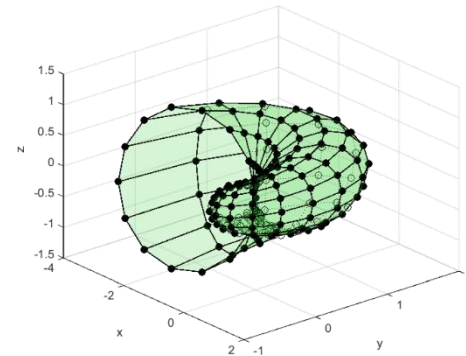
# Competition assignment

- assignments from previous semesters:

## Jacobi method



## Effective plotting



- see <https://cw.fel.cvut.cz/wiki/courses/a0b17mtb/projects/soutez>
- project can be selected by any number of students
- conditions:
  - project is completed according the assignment → credit award
  - project is the best one → winning the competition
    - prizes for the first three winners

# A0B17MTB – Course syllabus

1	Introduction, information on the course, MATLAB workspace, basic arithmetic operators, basic functions
2	Complex numbers, complex matrix design, matrix operations, element-by-element operations, introduction to vectorization, matrix dimension
3	Indexing, data type and size, output format
4	MATLAB Editor, script design, relation and logical operators, cells
5	Cycles, cycles vs. vectorization, control flow, program branching
6	Visualization in MATLAB #1, debugging
7	Set operations, sorting, searching, user-defined functions #1
8	Functions #2 (main functions, subfunctions, nested functions, anonymous functions)
9	Struct, strings, 'eval' and 'feval' functions, MATLAB path
10	Visualization in MATLAB #2, GUI #1
11	GUI #2
12	Date and time functions, error handling, I/O, basics of symbolic computations
13	Exercises , test
14	(Reserve)

# A0B17MTB – Deadlines

1	call for project proposals
2	
3	<i>bonus example (1-3 points)</i> , list of projects, discussion on own topics
4	
5	<i>short test (approx. 10-15 min) aimed on solving given problem in Matlab, 10 points</i>
6	<b>project choice</b>
7	<i>bonus example (1-3 points)</i>
8	<i>short test (approx. 10-15 min) aimed on solving given problem in Matlab, 10 points</i>
9	
10	<i>bonus example (1-3 points)</i>
11	
12	
13	<i>test (20 points), project hand-in (next-to-last week of the semester, 60 points), credit award</i>
14	reserve, competition assignment measurement

# Credit award

	Points	Min. points
Bonus example #1	2	10
Short test #1	10	
Bonus example #2	1	
Short test #2	10	
Bonus example #3	2	
Test	20	
Project	60	30

Grade	Points
A	90–100
B	80–89
C	70–79
D	60–69
E	50–59
F	0–49

# A0B17MTB – Schedule

- harmonogram of SS 2016/2017 (also on the web page):

	1. týden		2. týden		3. týden		4. týden		5. týden	
	20.2.	22.2.	27.2.	1.3.	6.3.	8.3.	13.3.	15.3.	20.3.	22.3.
	PO 16:15	ST 16:15	PO 16:15	ST 16:15	PO 16:15	ST 16:15	PO 16:15	ST 16:15	PO 16:15	ST 16:15
poznámka								Míla- Workshop	Míla-EuCap	Míla-EuCap
master	Viktor	Viktor	Viktor	Viktor	Míla	Míla	Viktor	Viktor	Viktor	Viktor
slave	Michal	Michal	Vít	Michal	Vít	Michal	Vít	Michal	Vít	Michal
náplň	1 (úvod)	1 (úvod)	2 (matice)	2 (matice)	3 (indexace)	3 (indexace)	4 (editor, relac. op.)	4 (editor, relac. op.)	5 (cykly, vetveni)	5 (cykly, vetveni)
harmonogram					bonusový příklad	bonusový příklad			1. písemka	1. písemka

Náplň předmětu:

1 (úvod)	5 (cykly, vetveni)	9 (textové řetězce)	13 (test, proj.)
2 (matice)	6 (vizual. 1)	10 (gui 1)	14 (rezerva)
3 (indexace)	7 (mnoz. op., fcn. 1)	11 (gui 2)	
4 (editor, relac. op.)	8 (funkce 2)	12 (bonusy)	
zadání projektů	1. písemka	2. písemka	test
			zápočet
			soutěž
			bonusový příklad

Pozn.: bonusový příklad je za 1-3b a vybrán ze šedých příkladů (případně zcela mimo slajdy).

Pozn.: věcná část harmonogramu může být postupně mírně zpožděna

	6. týden		7. týden		8. týden		9. týden		10. týden	
	27.3.	29.3.	3.4.	5.4.	10.4.	12.4.	17.4.	19.4.	24.4.	26.4.
	PO 16:15	ST 16:15	PO 16:15	ST 16:15	PO 16:15	ST 16:15	PO 16:15	ST 16:15	PO 16:15	ST 16:15
poznámka						Míla- habilitace	Velikonoční pondělí			
master	Míla	Míla	Míla	Míla	Míla	Viktor		Míla	Míla	Míla
slave	Vít	Michal	Vít	Michal	Vít	Michal		Michal	Vít	Michal
náplň	6 (vizual. 1)	6 (vizual. 1)	7 (mnoz. op., fcn. 1)	7 (mnoz. op., fcn. 1)	8 (funkce 2)	8 (funkce 2)		9 (textové řetězce)	9 (textové řetězce)	10 (gui 1)
harmonogram	zadání projektů	zadání projektů	bonusový příklad	bonusový příklad				2. písemka	2. písemka	bonusový příklad

	11. týden			12. týden			13. týden		14. týden		soutěž	
	1.5.	2.5.	3.5.	8.5.	10.5.	11.5.	15.5.	17.5.	22.5.	24.5.		
	PO 16:15	ÚT 16:15	ST 16:15	PO 16:15	ST 16:15	ČT 16:15	PO 16:15	ST 16:15	PO 16:15	ST 16:15		
poznámka	Svátek práce	Výuka jako v PO		Den osvobození		Výuka jako v PO		Rektorský den				
master		Míla	Vít		Michal	Vít	Michal		všichni	všichni		
slave		Vít	Míla		Míla	Míla	Míla					
náplň		10 (gui 1)	11 (gui 2)		12 (bonusy)	11 (gui 2)	12 (bonusy)		13 (test, proj.)	13 (test, proj.)		
harmonogram		bonusový příklad							test, zápočet	test, zápočet		soutěž

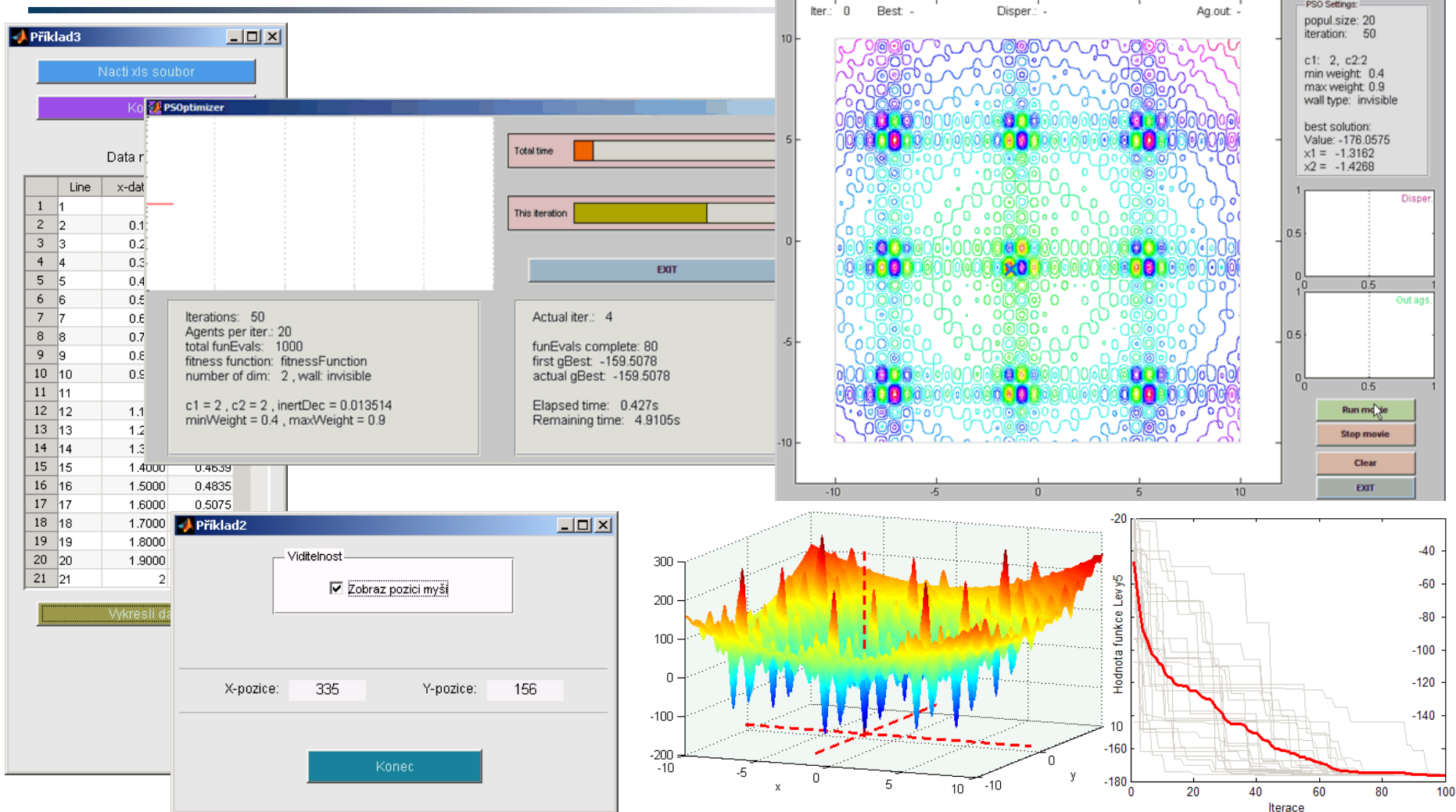
- this is how the bonus slides look like (see the background color...)

# A0B17MTB – Principles

- the aim of the course is to teach you something – if the presentation is too fast, be heard
- if you have an idea / proposal how to solve a problem in a more efficient way, put it forward
- can happen that the lecturer is not able to answer your question immediately, in that case the answer will be provided during the next lecture



# You will be able to ...



- see the [previous students' projects](#)

# Recommended literature, resources

- Matlab documentation

```
>> doc % opens the help browser
```

- Basic web-based textbooks on Matlab (so called primers)

- [www.mathworks.com/help/pdf\\_doc/matlab/getstart.pdf](http://www.mathworks.com/help/pdf_doc/matlab/getstart.pdf)
- <http://artax.karlin.mff.cuni.cz/~beda/cz/matlab/primercz/matlab-primer.html>

- Attaway, S.: Matlab – A Practical Introduction to Programming and Problem Solving, 3rd ed.

- available at Department's library

- Hahn, B. H., Valentine, D. T.: Essential Matlab, 5th Ed.

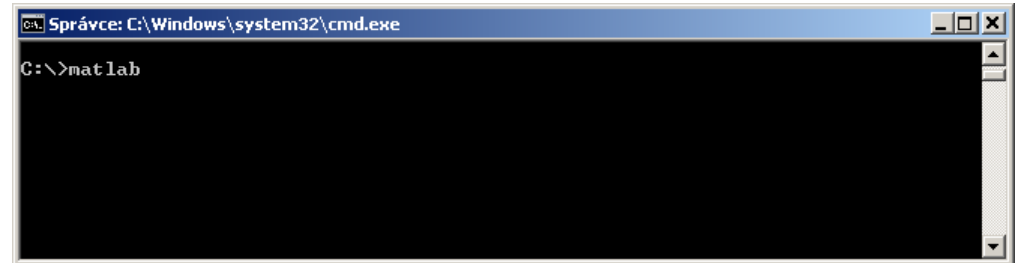
- available at Department's library

- other literature and sources will be mentioned during the semester...

# Launching Matlab



- command line
  - matlab



```
Správc: C:\Windows\system32\cmd.exe
C:\>matlab
```

- Matlab can be launched with a set of optional parameters (see later)
  - `matlab -r "test(10)"`
- 2016b: 2 GB RAM, 2 GB disk space (Matlab only), 4-6 GB typical installation, Win7 and newer
  - version dependent

# The Matlab Environment ( $\leq$ R2011b)

The screenshot shows the MATLAB 7.11.0 (R2010b) interface. The title bar indicates the version and includes standard window controls. The menu bar includes File, Edit, Debug, Parallel, Desktop, Window, and Help. The current folder is set to D:\Mila\Matlab\\_mfiles\TCMapp4.1a.

Numbered callouts highlight the following components:

- 1**: Command Window, showing the current workspace path and the prompt `>>`.
- 2**: Workspace window, displaying a table of variables:

Name	Value
c0	299792458
eps0	8.8542e-12


- 3**: Command History window, showing a list of executed commands and their timestamps.
- 4**: Current Folder window, showing a list of files and subfolders in the current directory.
- 5**: Details window, showing a message: "Select a file to view details".
- 6**: The MATLAB title bar.
- 7**: The Windows taskbar, showing the Start button and the system tray.
- 8**: The Windows taskbar, showing the system tray.

# The Matlab Environment ( $\geq$ R2011b)

The screenshot shows the MATLAB R2013a interface with the following components highlighted by numbered callouts:

- 1**: Command Window showing the execution of MATLAB code and the resulting output for matrices A, B, and variables a, b, c, d.
- 2**: Workspace window displaying a table of current variables in the workspace.
- 3**: Command History window showing a list of previously executed commands.
- 4**: Current Folder window showing the file explorer for the current directory.
- 5**: Details window at the bottom of the Current Folder pane.
- 6**: The MATLAB logo in the top-left corner of the application window.
- 7**: The top menu bar containing options like HOME, PLOTS, and APPS.
- 8**: The MATLAB title bar at the top of the window.

**Command Window Output:**

```
>> A = [-1 1; 1 -2]
B = [1 2 3; 4 5 6; 7 8 9]

A =

    -1     1
     1    -2

B =

     1     2     3
     4     5     6
     7     8     9

>> a = 1
b = 5;

a =

     1

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

c =

     1     0     0

d =

     0
     0
     1

fx>>
```

**Workspace Table:**

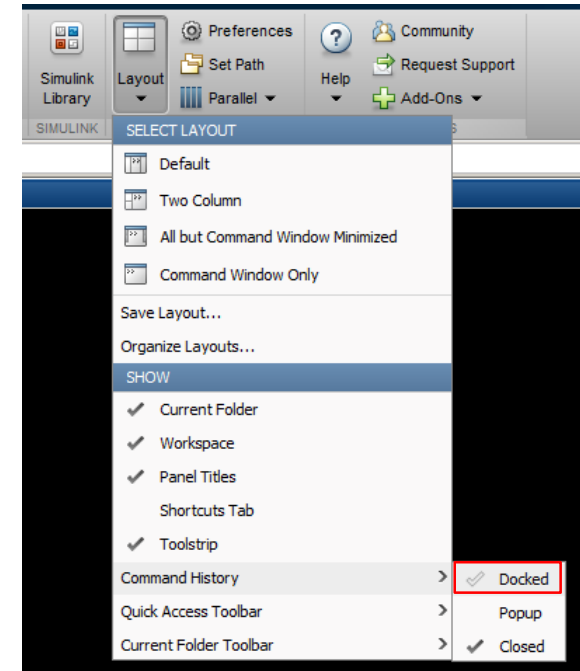
Name	Value	Min	Max
A	[-1 1 -2]	-2	1
B	[1 2 3; 4 5 6; 7 8 9]	1	9
a	1	1	1
b	5	5	5
c	[1 0 0]	0	1
d	[0;0;1]	0	1

**Command History:**

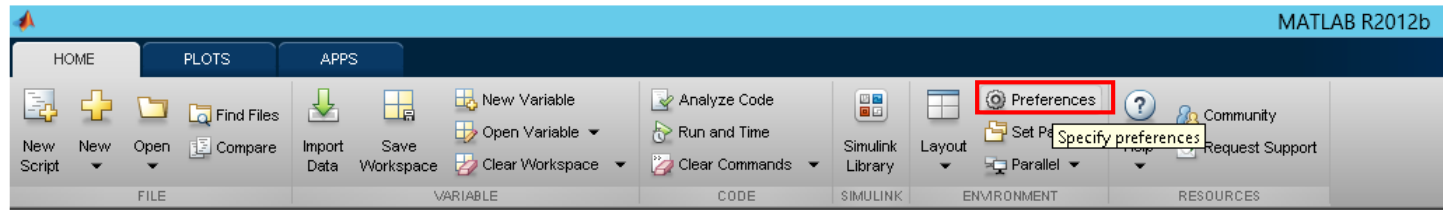
```
norm(A)
A
A = [-1 1; 1 -2], B = [1 2 3; 4 5 6; 7 8 9]
who
whos
size(filip)
filip
filip = []
size(filip)
size(filip)
whos
bar(B, 'DisplayName', 'B')
clear, clc
A = [-1 1; 1 -2]
B = [1 2 3; 4 5 6; 7 8 9]
a = 1
b = 5;
c = [1 0 0]
d = [0;0;1]
```

# The Matlab Environment – panels

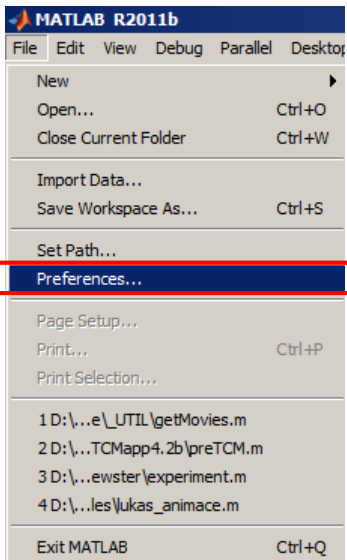
- 1 Command Window (CTRL+0)
- 2 Workspace (CTRL+3)
- 3 Command History (CTRL+1) – not activated in case of  $\geq$  R2015a; to activate...
- 4 Current Folder (CTRL+2)
- 5 Current Folder – Details
- 6 Current Folder (with history)
- 7 Start (Windows like), only for  $\leq$  Matlab R2011b
- 8 status



# Environment setting – basics

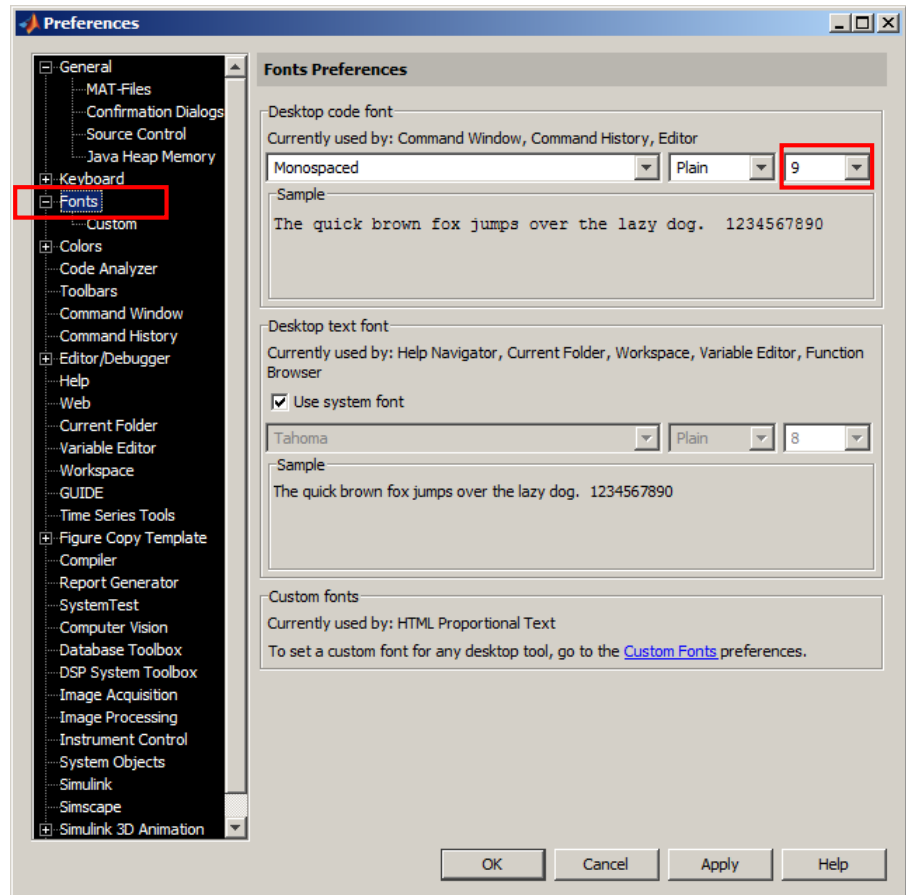


- Matlab R2012a and later
  - ribbon menu
- Matlab R2011b and older



```
>> preferences
```

- Font size



# Matlab termination

- always terminate Matlab in the command window

```
>> quit % terminates Matlab (and all windows)
>> exit %      -//-
```

- more advanced options (see documentation)

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

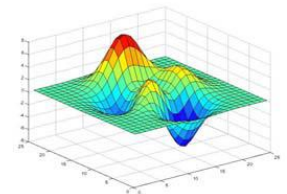
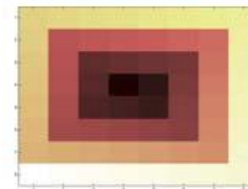
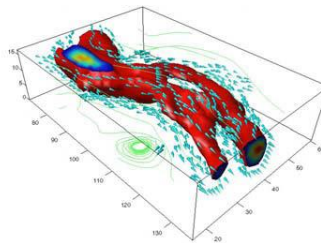


# Command line, documentation

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

```
>> help % Matlab help
```

```
>> demo % tutorials
```



# The Help structure, Matlab <R2011b

```
>> help % displays basic help contents
>> help sin % displays help related to sine function
```

```
>> help sin
SIN Sine of argument in radians.
SIN(X) is the sine of the elements of X.

See also asin, sind.

Overloaded methods:
codistributed/sin

Reference page in Help browser
doc sin
```

```
>>
```

The screenshot shows the MATLAB Help browser window. The left sidebar (1) contains a tree view of help topics, with 'Trigonometric' selected. The main content area (4) displays the 'sin' function page, including its syntax ( $Y = \sin(X)$ ), description, definitions, and examples. A graph of the sine function is shown at the bottom. Red circles with numbers 1, 2, 3, and 4 highlight specific elements: 1 points to the sidebar, 2 points to the 'Definitions' section, 3 points to the search bar, and 4 points to the breadcrumb navigation.

```
>> doc % launches help window
>> doc sin % sine function
% related help
```

# The Help structure, Matlab >R2011b

The screenshot displays the MATLAB Help documentation for the `sin` function. The interface includes a search bar at the top right (labeled '3') and a navigation sidebar on the left (labeled '4'). The main content area is titled 'sin' and contains the following sections:

- Syntax:** `Y = sin(X)` (labeled 'example')
- 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 in the interval  $[-\text{Inf}, \text{Inf}]$ , `sin` returns real values in the interval  $[-1, 1]$ . For complex values of X, `sin` returns complex values. All angles are in radians. (labeled '2')
- Examples:** Plot Sine Function (labeled 'collapse all'). The example code is:
 

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

A plot of the sine function is shown at the bottom, with the x-axis ranging from  $-\pi$  to  $\pi$  and the y-axis ranging from 0 to 1. The plot shows a blue curve representing the sine function.

# Matlab Help

240 s



- start and terminate Matlab
- set the Matlab environment to your taste
  
- try to launch the help
- find the documentation of the following functions: `sin`, `cos`, `abs`
- browse through individual help chapters
  - pay attention to the part *Getting Started*

# Shortcuts Command Window

key	meaning
ENTER	sends line for processing
ESC	deletes whole line
DEL	deletes one character (right to the cursor)
BACKSPACE	deletes one character (left to the cursor)
HOME	moves cursor to the beginning of line
END	moves cursor to the end of line
CTRL + ↑	moves cursor to the beginning of next word
CTRL + ↓	moves cursor to the beginning of previous word
SHIFT + ENTER	sends cursor to the next line
CTRL + K	deletes all to the right of cursor
CTRL + C	forces interruption of Matlab (e.g. long / erroneous calculation)
CTRL + TAB	switching between windows of Matlabu Environment
↓ a ↑	command history listing (searching is available CTRL+F)
F1	context help related to the word where the cursor is placed (Command Window, Editor)
TAB	function or variable name hint

+ usual Windows shortcuts for text processing

# Searching the Help

key / command	meaning
SHIFT + F1	when pressed in command line, opens searchable function library
F9	evaluation of selected part of the code in Editor
NOT, OR, AND	it is possible to use logical operators in documentation search
*	it is possible to use wildcards in documentation search
""	to search exact phrase in documentation

```
>> docsearch "plot tools"
```

```
>> docsearch plot* tools
```

# Discussed functions

---

---

quit, exit	terminates Matlab	•
preferences	opens Matlab preferences	
doc, help, demo	commands related to documentation and help	•
sin, cos	sample goniometric functions	
abs	absolute value	

---

# Thank you!



ver. 7.1. (20/02/2017)  
Miloslav Čapek (C), Pavel Valtr (E)  
miloslav.capek@fel.cvut.cz  
Pavel.Valtr@fel.cvut.cz

Apart from educational purposes at CTU, this document may be reproduced,  
stored or transmitted only with the prior permission of the authors.  
Document created as part of A0B17MTB course.

