

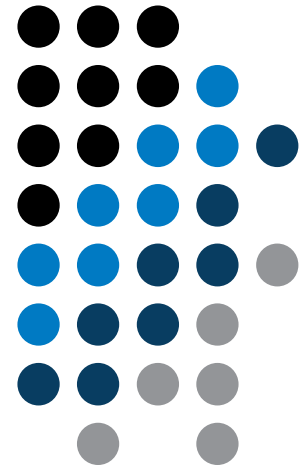
A0B17MTB – Matlab

Introduction

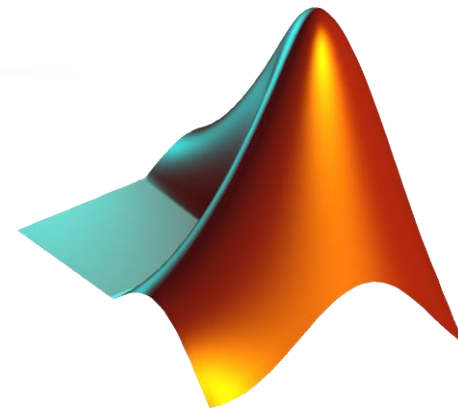


Miloslav Čapek
miloslav.capek@fel.cvut.cz
Filip Kozák, Viktor Adler, Pavel Valtr

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` + main access password
 - `fel.cvut.cz` → computer network → Multi-license software at CTU

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...
 - ... R2015b is the newest version of Matlab
 - local distribution: Humusoft

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 (14th week is a ‘reserve’)
 - 10 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 semestr, **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

Data types

Code execution

Visualization

Relation and logical operators

Matrix operations

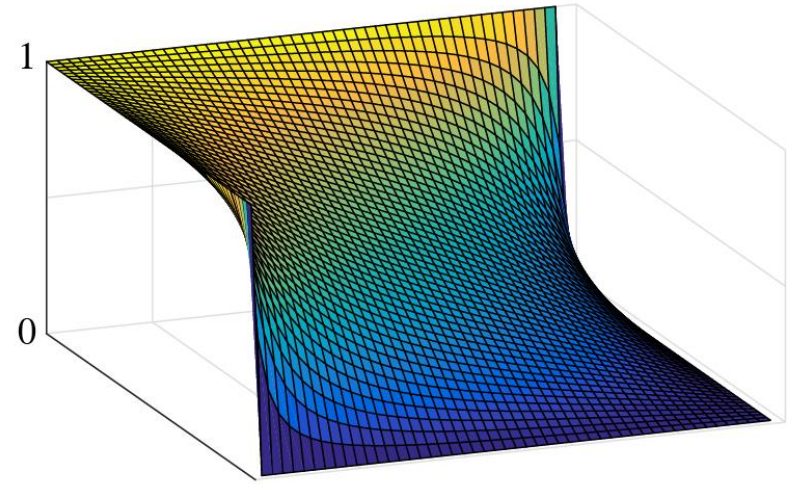
User scripts and functions

Numerical methods

Symbolic math

Competition assignment

Jacobi method



- see <https://cw.fel.cvut.cz/wiki/courses/a0b17mtb/start>
> projects > seznam_projektu
- 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, MATLAB Editor, script design
4	Cycles, relation and logical operators, cycles vs. vectorization, control flow #1
5	Control flow #2, visualization in MATLAB #1, debugging #1
6	Set operations, sorting, searching, user-defined functions #1
7	User interface (main functions, subfunctions, nested functions, anonymous functions)
8	Struct, Strings, 'eval' and 'feval' functions, MATLAB path
9	Visualization in MATLAB #2, GUI #1
10	GUI #2
11	Date and time functions, error handling, cell, I/O, basics of symbolic computations
12	MATLAB profile, p-code, numerical accuracy, publishing MATLAB code, programming style guidelines
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	<i>short test (approx. 10-15 min) aimed on solving given problem in Matlab, 10 points</i>
5	project choice
6	
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>project hand-in (next-to-last week of the semester), test</i>
14	test evaluation, credit award

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 2015/2016 (also on the web page):

	8. týden			9. týden			10. týden			11. týden			12. týden		
	22. 2.	23. 2.	24. 2.	29. 2.	1. 3.	2. 3.	7. 3.	8. 3.	9. 3.	14. 3.	15. 3.	16. 3.	21. 3.	22. 3.	24. 3.
	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16
poznámka							Filip - hory								
master	M	M	M	M	M	M	P	P	P	F	F	F	F	F	F
slave	F	F	F	F	F	F	V	V	V	V	V	V	M	M	M
náplň	1 (úvod)	1 (úvod)	1 (úvod)	2 (matice)	2 (matice)	2 (matice)	3 (indexace)	3 (indexace)	3 (indexace)	4 (relac. op., cykly)	4 (relac. op., cykly)	4 (relac. op., cykly)	5 (if, vizualizace)	5 (if, vizualizace)	5 (if, vizualizace)
harmonogram							bonusový příklad	bonusový příklad	bonusový příklad	1. písemka	1. písemka	1. písemka	zadání projektů	zadání projektů	zadání projektů

Náplň předmětu:

1 (úvod)	5 (if, vizualizace)	9 (gui1)	13 (zápočet)
2 (matice)	6 (mnoz. op.)	10 (gui2)	14 (rezerva)
3 (indexace)	7 (funkce 2)	11 (bonusy)	
4 (relac. op., cykly)	8 (textové řetězce)	12 (velké příklady)	
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 o

	13. týden			14. týden			15. týden			16. týden			17. týden		
	28. 3.	29. 3.	30. 3.	4. 4.	5. 4.	6. 4.	11. 4.	12. 4.	13. 4.	18. 4.	19. 4.	20. 4.	25. 4.	26. 4.	27. 4.
	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16
poznámka	Velikonoční pondělí						Mila, Pavel - EuCAP								
master		V	V	V	V	V	V	V	V	V	F	F	F	F	F
slave		M	M	M	F	F	F	F	F	F	M	M	M	M	M
náplň		6 (mnoz. op.)	6 (mnoz. op.)	6 (mnoz. op.)	7 (funkce 2)	7 (funkce 2)	7 (funkce 2)	8 (textové řetězce)	8 (textové řetězce)	8 (textové řetězce)	9 (gui1)	9 (gui1)	9 (gui1)	10 (gui2)	10 (gui2)
harmonogram					bonusový příklad	bonusový příklad	bonusový příklad	2. písemka	2. písemka	2. písemka				bonusový příklad	bonusový příklad

F - Filip
M - Mila
V - Viktor



	18. týden			19. týden			20. týden			21. týden			soutěž		
	2. 5.	3. 5.	4. 5.	9. 5.	10. 5.	11. 5.	16. 5.	17. 5.	18. 5.	23. 5.	24. 5.	25. 5.			
	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16	PO 16:15	UT 16:15	ST 16:16			
poznámka						rektorský den									
master	F	V	V	V	M		M	M	M	M,V,F	M,V,F	M,V,F			
slave	M	F	F	F											
náplň	10 (gui2)	11 (bonusy)	11 (bonusy)	11 (bonusy)	12 (velké příklady)		12 (velké příklady)	13 (zápočet)	12 (velké příklady)	13 (zápočet)	14 (rezerva)	13 (zápočet)			
harmonogram	bonusový příklad						test	test	test	zápočet	zápočet	zápočet			soutěž

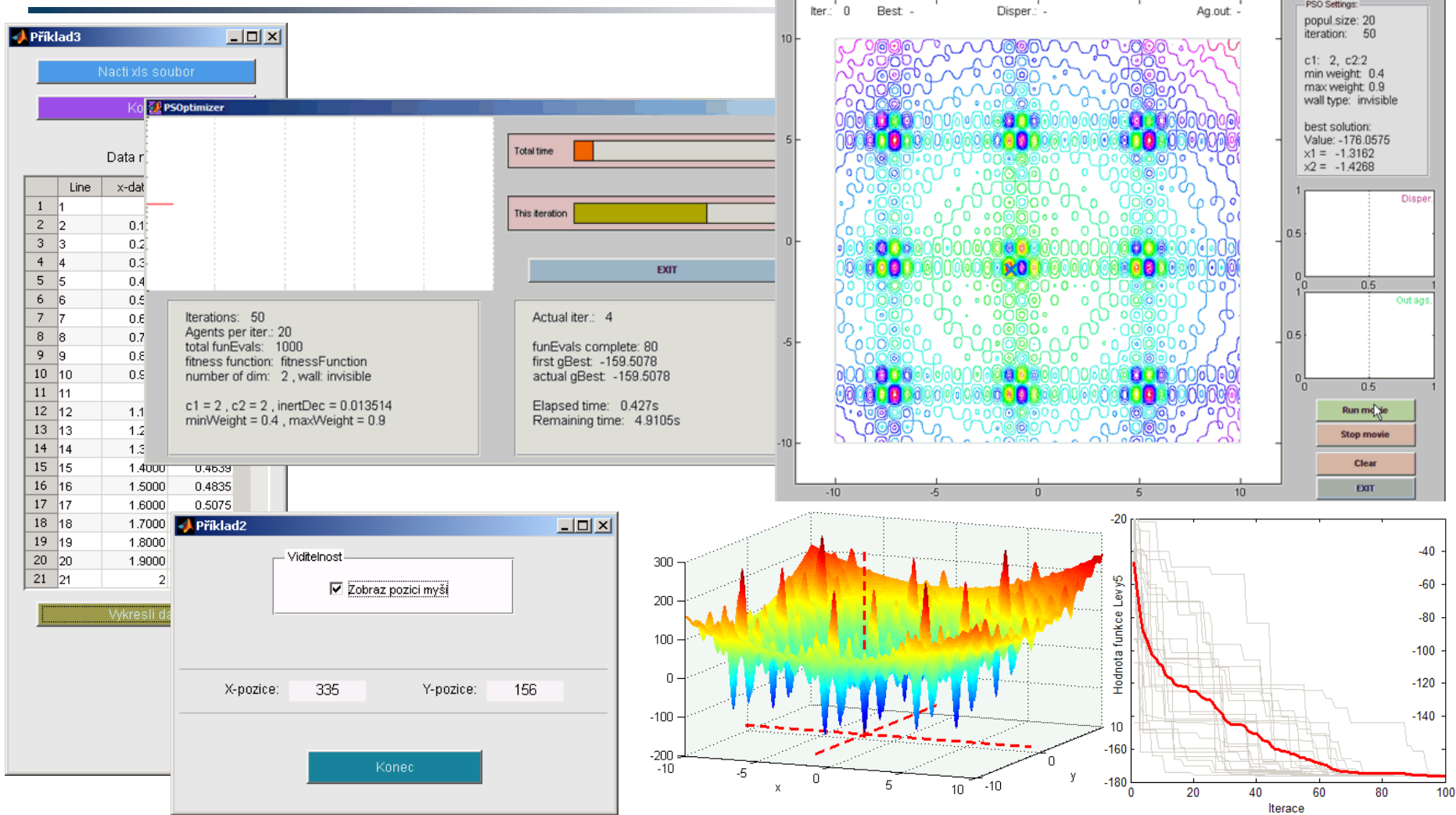
bude doplněno (viz web)

- 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 <http://elmag.org/cs/Matlab/projekty> for 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://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.

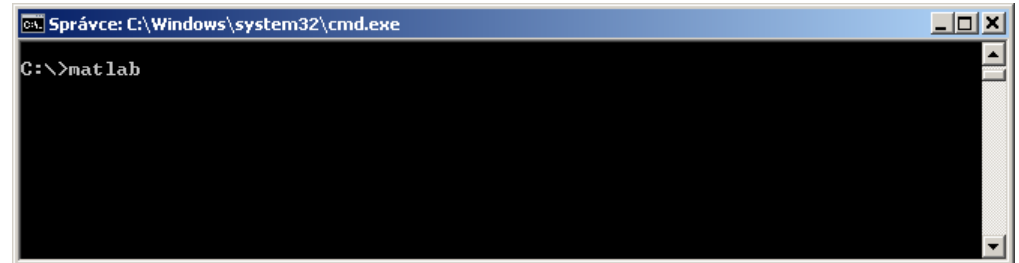
- available at Department's library

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

Launching Matlab



- command line
 - matlab



```
GA Správce: C:\Windows\system32\cmd.exe
C:\>matlab
```

- Matlab can be launched with a set of optional parameters (see later)
 - `matlab -r "test(10)"`
- version dependent, up to 500MB RAM (win7) per matlab thread

The Matlab Environment (\leq R2011b)

The screenshot shows the MATLAB 7.11.0 (R2010b) interface. The main window is titled "MATLAB 7.11.0 (R2010b)" and contains several panes:

- Current Folder:** Shows a file explorer view of the current directory, `D:\Mila\Matlab_mfiles\TCMapp4.1a`. A red box highlights this pane, with a callout '4' pointing to a file named `preTCMinit.m`.
- Command Window:** Displays the current workspace and command prompt. A red box highlights this pane, with a callout '1' pointing to the command prompt area.
- Workspace:** Shows the current workspace variables. A red box highlights this pane, with a callout '2' pointing to the workspace area.
- Command History:** Shows a list of commands entered in the Command Window. A red box highlights this pane, with a callout '3' pointing to the command history area.
- Details:** A pane at the bottom left of the Current Folder pane, used for viewing details of a selected file. A red box highlights this pane, with a callout '5' pointing to it.
- Taskbar:** The Windows taskbar at the bottom shows the Start button and the MATLAB application icon. A red box highlights the taskbar area, with callouts '7' and '8' pointing to the Start button and the MATLAB icon, respectively.

The Command Window displays the following text:

```
C:\Program Files\MATLAB\R2010b\bin
Workspace is changing to:
D:\Mila\Matlab\_mfiles
August 31, 2011 9:00:45.868 PM
Keep on working...
>>
```

The Command History pane shows the following commands:

```
clear,clc
-- 18.8.2011 19:31 --
clear,clc,preTCM
plotEigNum(pTCMout)
plotEigNum(pTCMout2)
postTCM(pTCMout)
postTCM(pTCMout2)
plotEigNum(pTCMout)
plotEigNum(pTCMout)
-- 29.8.2011 18:55 --
doc
clear,clc
-- 30.8.2011 11:32 --
bench
doc bench)
edit bench
clear,clc,quit
-- 31.8.2011 21:00 --
```

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 workspace variables.
- 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 window title bar.
- 7**: The menu bar (HOME, PLOTS, APPS) and the toolbar.
- 8**: The MATLAB logo in the bottom-left corner of the window title bar.

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:

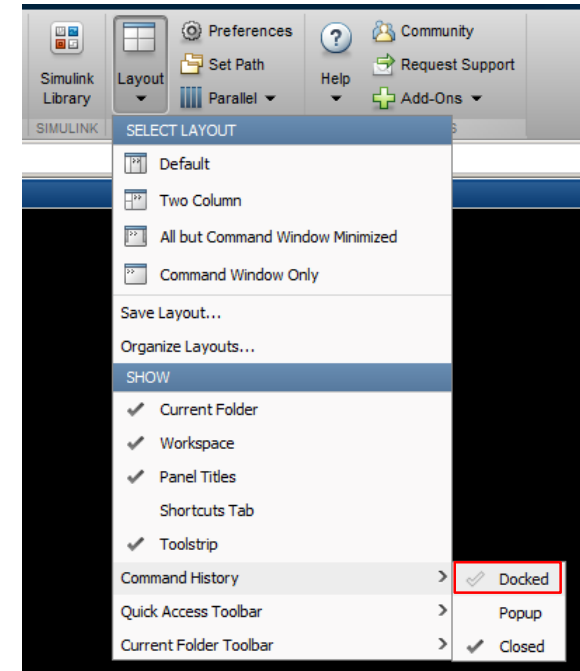
Name	Value	Min	Max
A	[-1 1 -2]	-2	1
B	[1 2 3; 4 5 6; 7 8 9]	1	9
a	1	1	1
b	5	5	5
c	[1 0 0]	0	1
d	[0;0;1]	0	1

Command History:

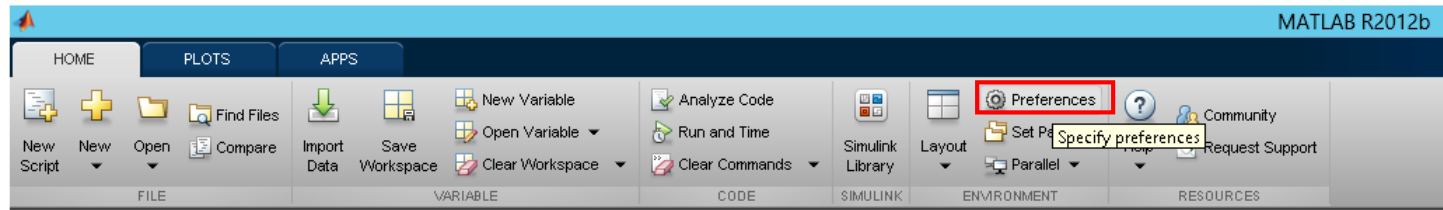
```
norm(A)
A
A = [-1 1; 1 -2], B = [1 2 3; 4 5 6; 7 8 9]
who
whos
size(filip)
filip
filip = []
size(filip)
size(filip)
whos
bar(B, 'DisplayName', 'B')
clear, clc
A = [-1 1; 1 -2]
B = [1 2 3; 4 5 6; 7 8 9]
a = 1
b = 5;
c = [1 0 0]
d = [0;0;1]
```

The Matlab Environment – panels

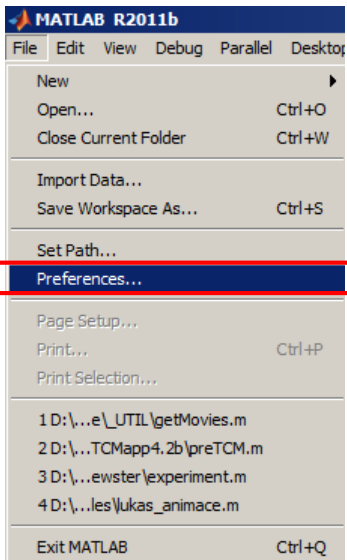
- 1 Command Window (CTRL+0)
- 2 Workspace (CTRL+3)
- 3 Command History (CTRL+1) – not activated in case of \geq R2015a; to activate...
- 4 Current Folder (CTRL+2)
- 5 Current Folder – Details
- 6 Current Folder (with history)
- 7 Start (Windows like), only for \leq Matlab R2011b
- 8 status



Environment setting – basics

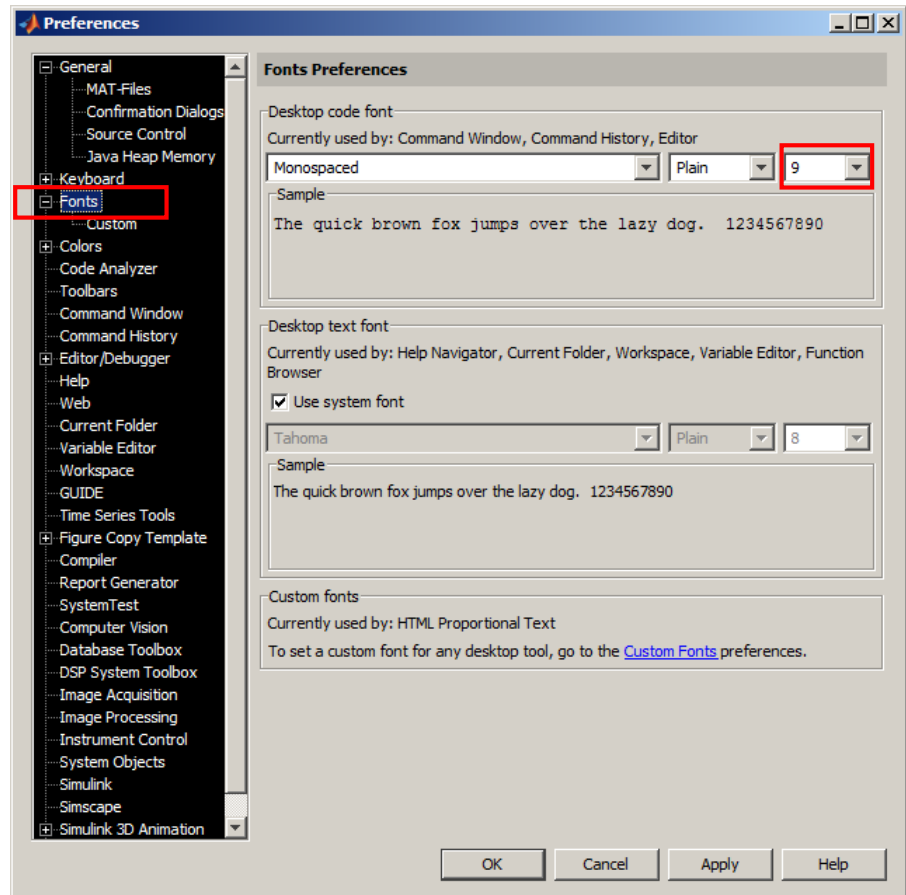


- Matlab R2012a and later
 - ribbon menu
- Matlab R2011b and older



```
>> preferences
```

- Font size



Matlab termination

- always terminate Matlab in the command window

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

- more advanced options (see documentation)

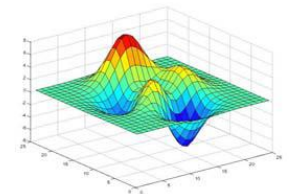
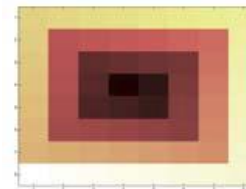
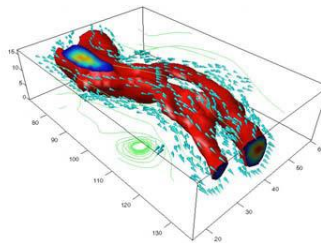
```
>> quit cancel
>> exit force
```


Command line, documentation

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

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

```
>> demo % tutorials
```



The Help structure

```
>> 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 the help structure, with 'Trigonometric' selected. The main content area (4) displays the 'sin' function page, which includes the following sections:

- Syntax:** $Y = \sin(X)$
- Description:** $Y = \sin(X)$ returns the circular sine of the elements of X . The `sin` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.
- Definitions:** The sine of an angle is: $\sin(x) = \frac{e^{ix} - e^{-ix}}{2i}$. For complex x : $\sin(x+iy) = \sin(x)\cosh(y) + i\cos(x)\sinh(y)$.
- Examples:** Graph the sine function over the domain $-\pi \leq x \leq \pi$.

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

A graph of the sine function is shown at the bottom of the page.

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

The Help structure, Matlab >R2011b

Help

Search Document **3**

MATLAB > Mathematics > Elementary Math > Trigonometry **4**

sin
Sine of argument in radians

Syntax
 $Y = \sin(X)$

Description
 $Y = \sin(X)$ returns the circular sine of the elements of X . The `sin` function operates element-wise on arrays. The function's domains and ranges include complex values. All angles are in radians.

Examples **2**
Graph the sine function over the domain $-\pi \leq x \leq \pi$.

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

file:///C:/Program Files/MATLAB/R2012b/help/matlab/index.html#mathematics

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. 5.1 (19/02/2016)
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.

