A0B17MTB – Matlab

Introduction

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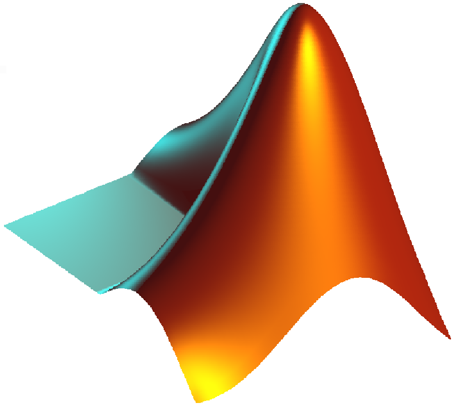
You will learn …



What is MATLAB?

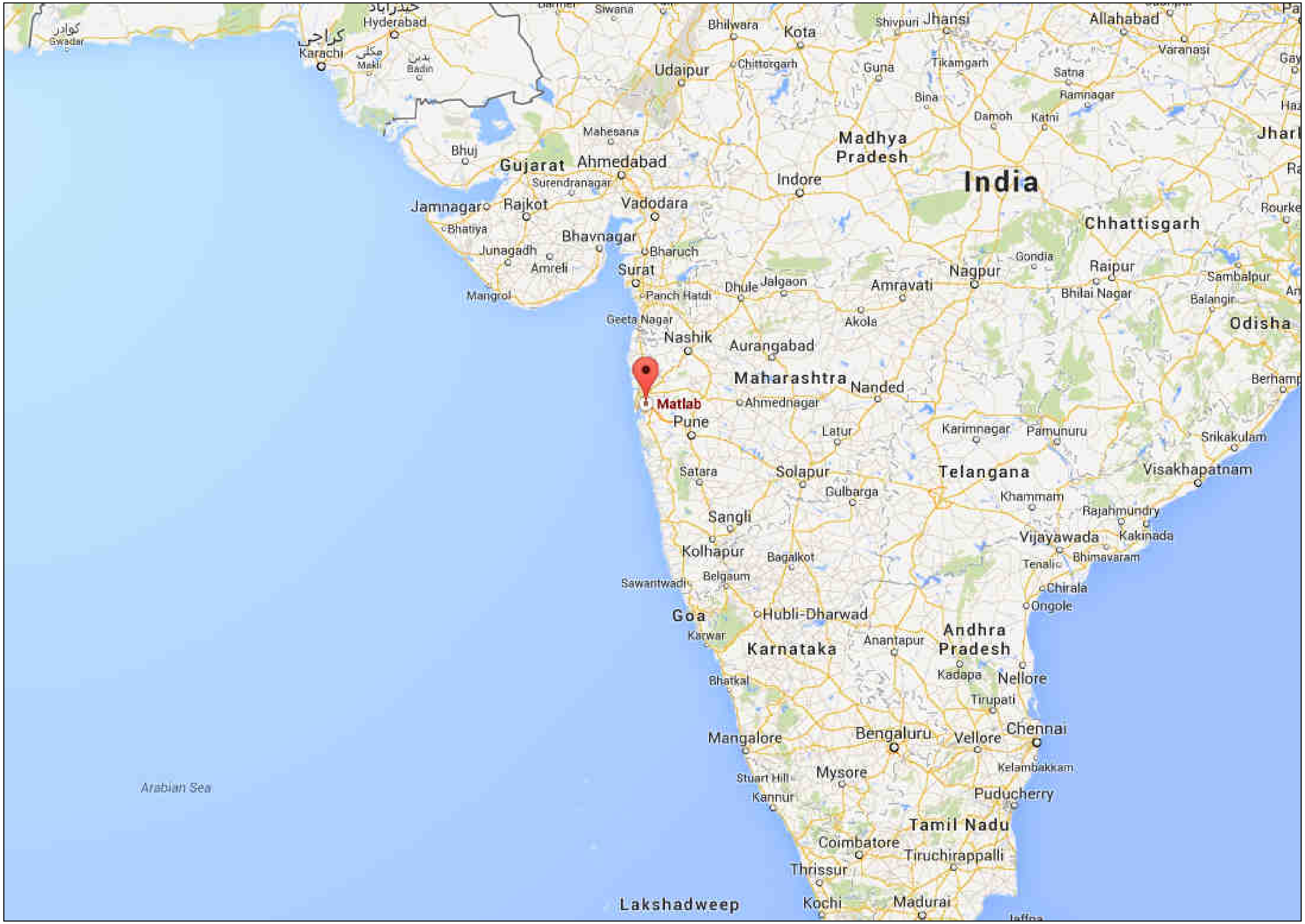
Why to learn MATLAB?

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...
  - ... 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 physisists
- 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

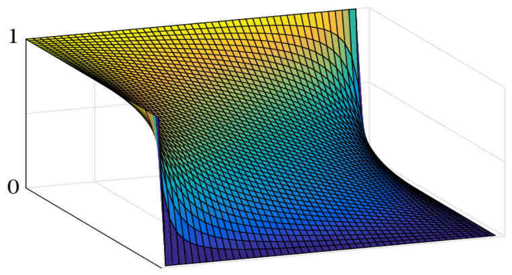
A0B17MTB

- 13 weeks (14th week is a ‘reserve’)
  - 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 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
- https://cw.fel.cvut.cz/wiki/courses/a0b17mtb/start

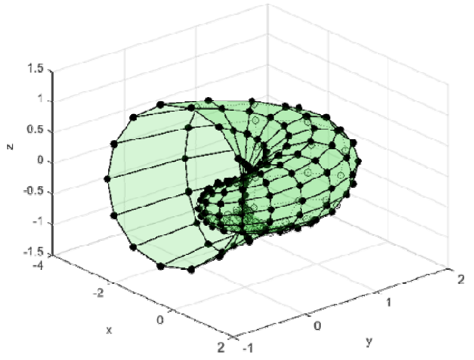
Competition assignment

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

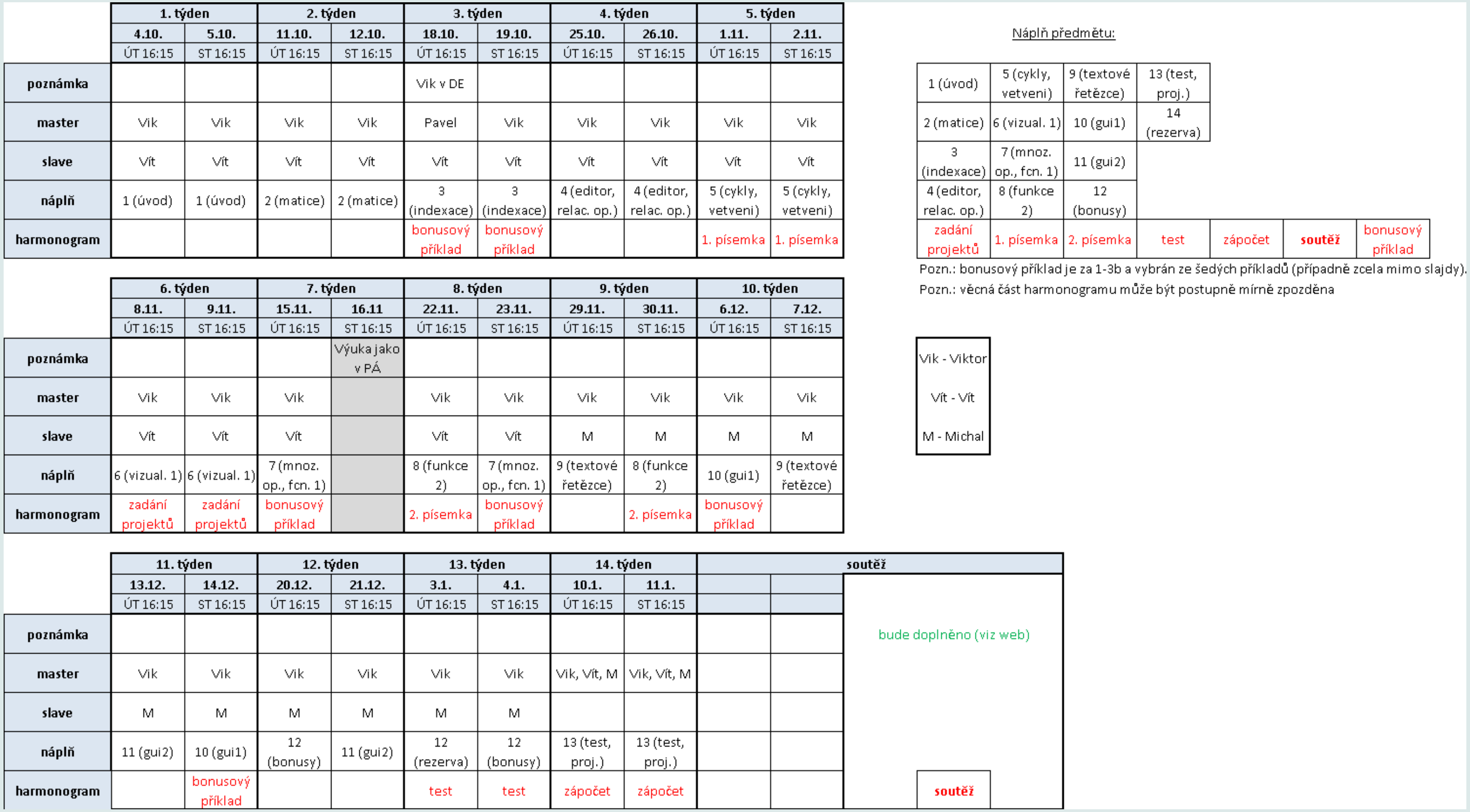
Credit award

	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	10
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 WS 2016/2017 (also on the web page):



	1. týden		2. týden		3. týden		4. týden		5. týden	
	4.10.	5.10.	11.10.	12.10.	18.10.	19.10.	25.10.	26.10.	1.11.	2.11.
	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15
poznámka					Vik v DE					
master	Vik	Vik	Vik	Vik	Pavel	Vik	Vik	Vik	Vik	Vik
slave	Vít	Vít	Vít	Vít	Vít	Vít	Vít	Vít	Vít	Vít
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

	6. týden		7. týden		8. týden		9. týden		10. týden	
	8.11.	9.11.	15.11.	16.11	22.11.	23.11.	29.11.	30.11.	6.12.	7.12.
	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15
poznámka				Výuka jako v PÁ						
master	Vik	Vik	Vik		Vik	Vik	Vik	Vik	Vik	Vik
slave	Vít	Vít	Vít		Vít	Vít	M	M	M	M
náplň	6 (vizual. 1)	6 (vizual. 1)	7 (mnoz. op., fcn. 1)		8 (funkce 2)	7 (mnoz. op., fcn. 1)	9 (textové řetězce)	8 (funkce 2)	10 (gui1)	9 (textové řetězce)
harmonogram	zadání projektů	zadání projektů	bonusový příklad		2. písemka	bonusový příklad		2. písemka	bonusový příklad	

	11. týden		12. týden		13. týden		14. týden		soutěž		
	13.12.	14.12.	20.12.	21.12.	3.1.	4.1.	10.1.	11.1.			
	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15	ÚT 16:15	ST 16:15			
poznámka											bude doplněno (viz web)
master	Vik	Vik	Vik	Vik	Vik	Vik	Vik, Vít, M	Vik, Vít, M			
slave	M	M	M	M	M	M					
náplň	11 (gui2)	10 (gui1)	12 (bonusy)	11 (gui2)	12 (rezerva)	12 (bonusy)	13 (test, proj.)	13 (test, proj.)			
harmonogram		bonusový příklad			test	test	zápočet	zápočet			**soutěž**

Náplň předmětu:

1 (úvod)	5 (cykly, vetveni)	9 (textové řetězce)	13 (test, proj.)			
2 (matice)	6 (vizual. 1)	10 (gui1)	14 (rezerva)			
3 (indexace)	7 (mnoz. op., fcn. 1)	11 (gui2)				
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 zpozděna

Vik - Viktor

Vít - Vít

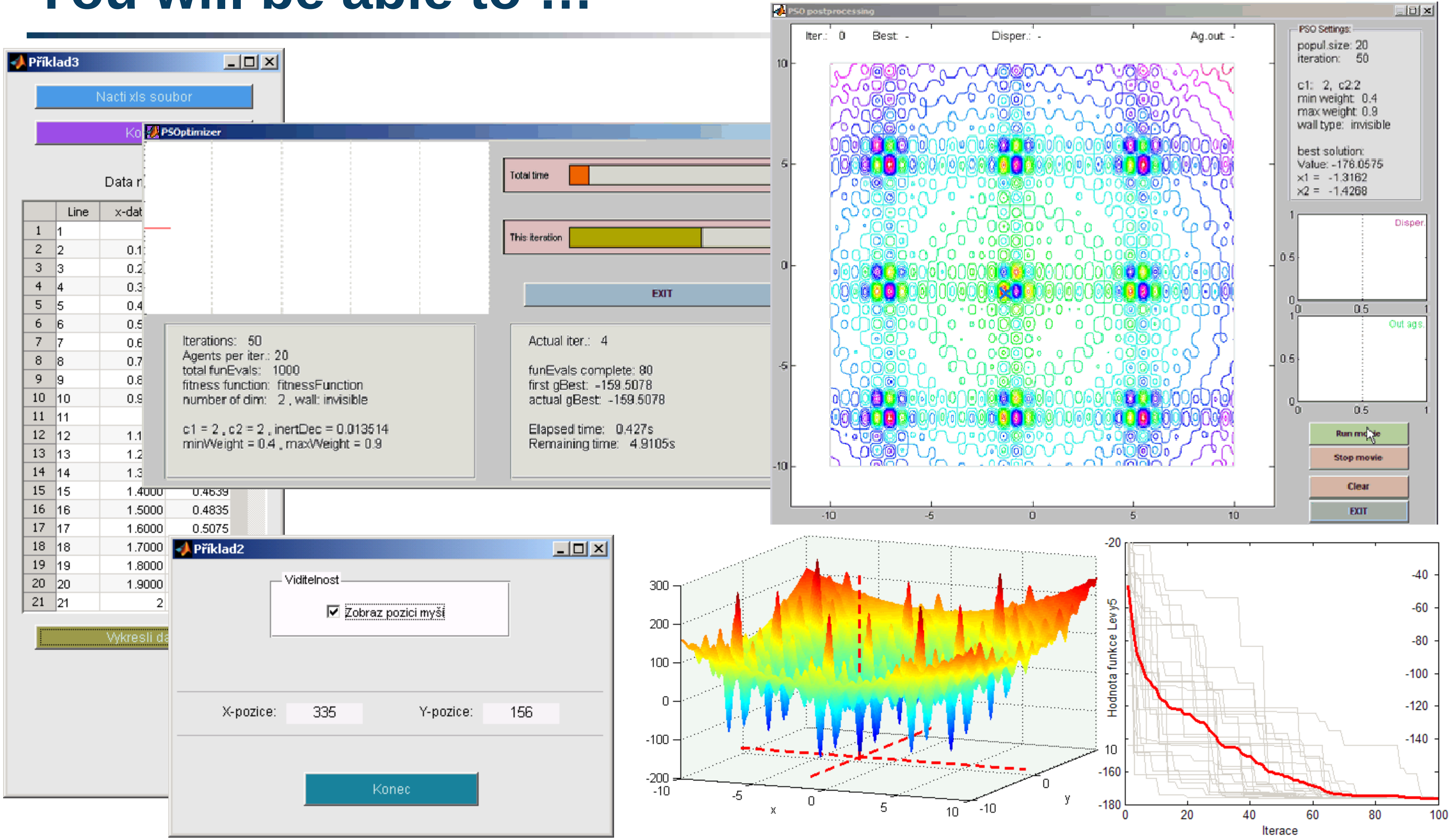
M - Michal

- 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 to 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 …



	Line	x-dat	
1	1		
2	2	0.1	
3	3	0.2	
4	4	0.3	
5	5	0.4	
6	6	0.5	
7	7	0.6	
8	8	0.7	
9	9	0.8	
10	10	0.9	
11	11		
12	12	1.1	
13	13	1.2	
14	14	1.3	
15	15	1.4000	0.4639
16	16	1.5000	0.4835
17	17	1.6000	0.5075
18	18	1.7000	
19	19	1.8000	
20	20	1.9000	
21	21	2	

Iterations: 50
Agents per iter.: 20
total funEvals: 1000
fitness function: fitnessFunction
number of dim: 2 , wall: invisible

c1 = 2 , c2 = 2 , inertDec = 0.013514
minWeight = 0.4 , maxWeight = 0.9

Actual iter.: 4

funEvals complete: 80
first gBest: -159.5078
actual gBest: -159.5078

Elapsed time: 0.427s
Remaining time: 4.9105s

PSO Settings:
popul.size: 20
iteration: 50

c1: 2, c2:2
min weight: 0.4
max weight: 0.9
wall type: invisible

best solution:
Value: -176.0575
x1 = -1.3162
x2 = -1.4268

☑ Zobraz pozici myši

X-pozice: 335 Y-pozice: 156

- 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://artax.karlin.mff.cuni.cz/~beda/cz/matlab/primercz/matlab-primer.html`

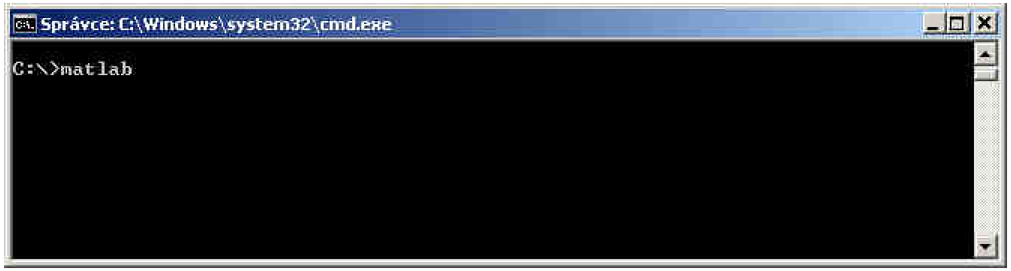
- Attaway, S.: Matlab – A Practical Introduction to Programming and Problem Solving, 3rd ed.
  - available at Department’s library

- 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`

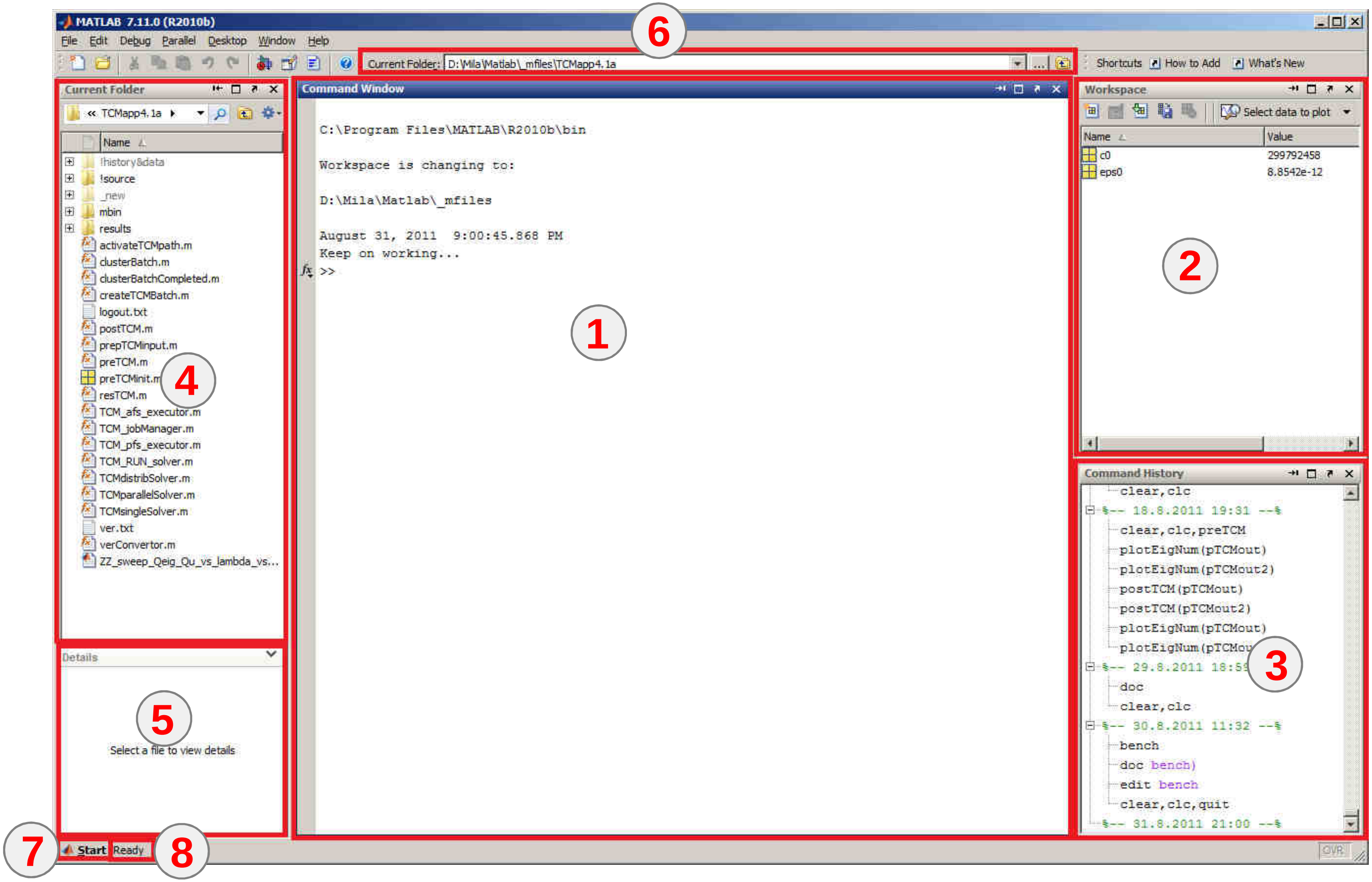


```
C:\>matlab
```

- 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 (≤ R2011b)



Current Folder: D:\Mila\Matlab_mfiles\TCMapp4.1a

« TCMapp4.1a

Name
- !history&data
- !source
- _new
- mbin
- results
- activateTCMpath.m
- clusterBatch.m
- clusterBatchCompleted.m
- createTCMBatch.m
- logout.txt
- postTCM.m
- prepTCMinput.m
- preTCM.m
- preTCMinit.m
- resTCM.m
- TCM_afs_executor.m
- TCM_jobManager.m
- TCM_pfs_executor.m
- TCM_RUN_solver.m
- TCMdistribSolver.m
- TCMparallelSolver.m
- TCMsingleSolver.m
- ver.txt
- verConvertor.m
- ZZ_sweep_Qeig_Qu_vs_lambda_vs...

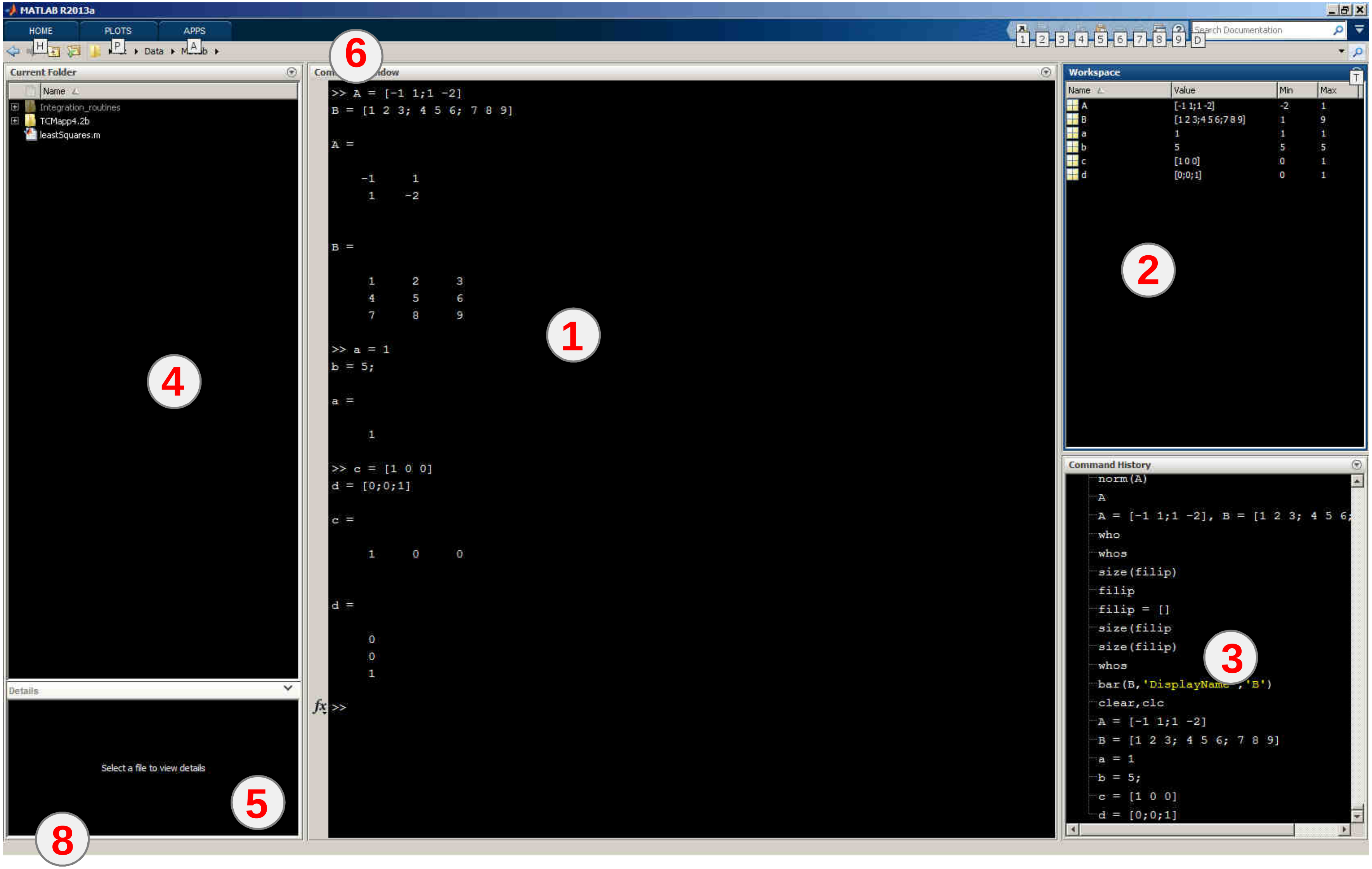
Select a file to view details

```
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...
>>
```

Name	Value
c0	299792458
eps0	8.8542e-12

```
 clear,clc
%-- 18.8.2011 19:31 --%
 clear,clc,preTCM
 plotEigNum(pTCMout)
 plotEigNum(pTCMout2)
 postTCM(pTCMout)
 postTCM(pTCMout2)
 plotEigNum(pTCMout)
 plotEigNum(pTCMou
%-- 29.8.2011 18:5
 doc
 clear,clc
%-- 30.8.2011 11:32 --%
 bench
 doc bench)
 edit bench
 clear,clc,quit
%-- 31.8.2011 21:00 --%
```

The Matlab Environment (≥ R2011b)



```
>> 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

>>
```

Name	Value	Min	Max
A	[-1 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

```
norm(A)
A
A = [-1 1;1 -2], B = [1 2 3; 4 5 6;
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 ≥ R2015a; to activate...

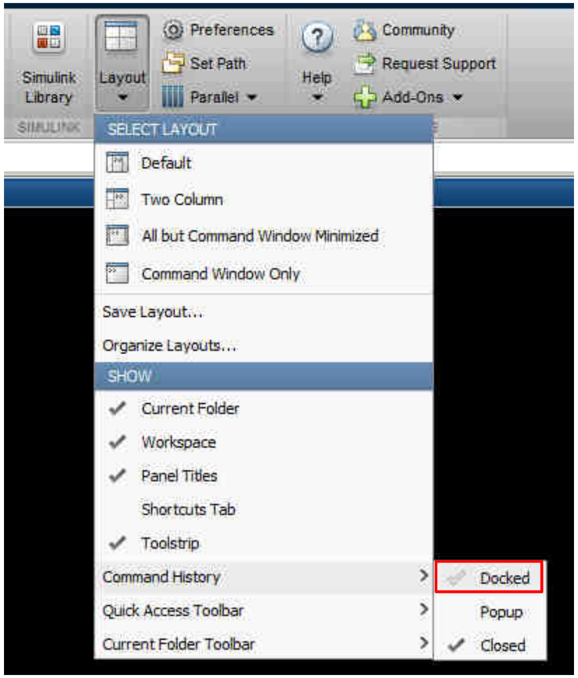
4 Current Folder (CTRL+2)

5 Current Folder – Details

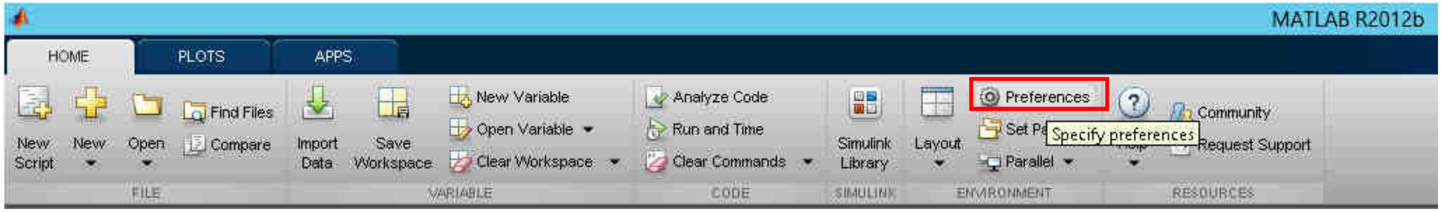
6 Current Folder (with history)

7 Start (Windows like), only for ≤ Matlab R2011b

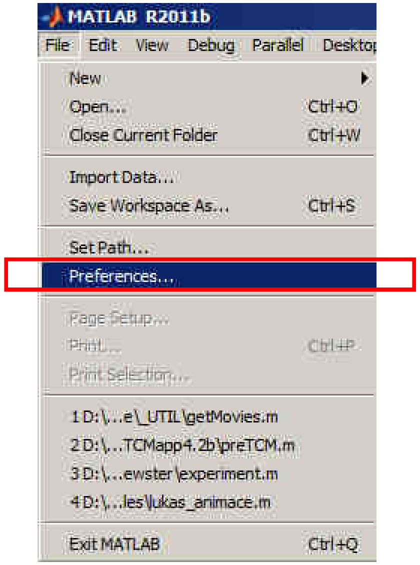
8 status



Environment setting – basics

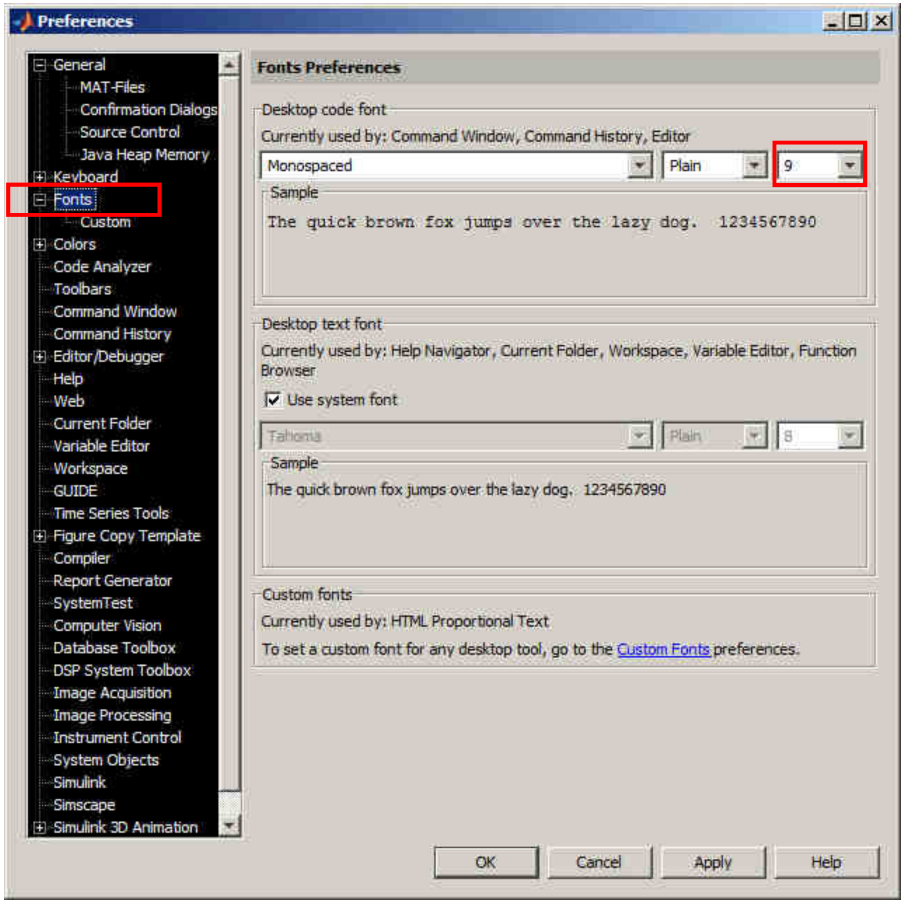


- Matlab R2012a and later
  - ribbon menu
- Matlab R2011b and older



```
>> preferences
```

- Font size



Fonts Preferences

Desktop code font

Currently used by: Command Window, Command History, Editor

Monospaced | Plain | 9

Sample

The quick brown fox jumps over the lazy dog. 1234567890

Desktop text font

Currently used by: Help Navigator, Current Folder, Workspace, Variable Editor, Function Browser

☑ Use system font

Tahoma | Plain | 8

Sample

The quick brown fox jumps over the lazy dog. 1234567890

Custom fonts

Currently used by: HTML Proportional Text

To set a custom font for any desktop tool, go to the Custom Fonts preferences.

Matlab termination

- always terminate Matlab in the command window

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

- more advanced options (see documentation)

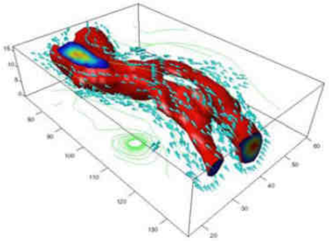
```
>> quit cancel
>> exit force
```

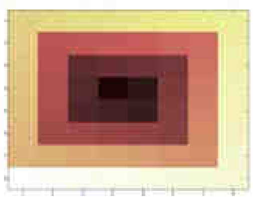
Command line, documentation

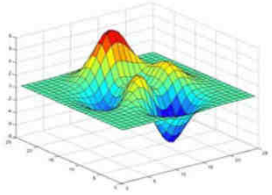
```
>> doc % opens documentation window
```

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

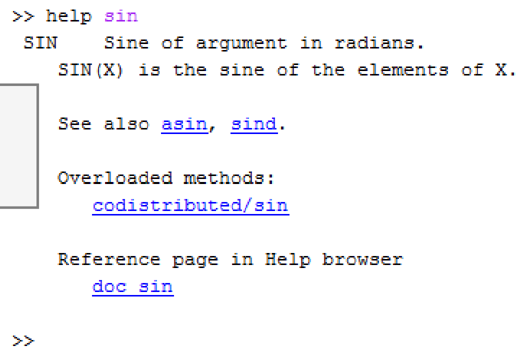
```
>> demo % tutorials
```





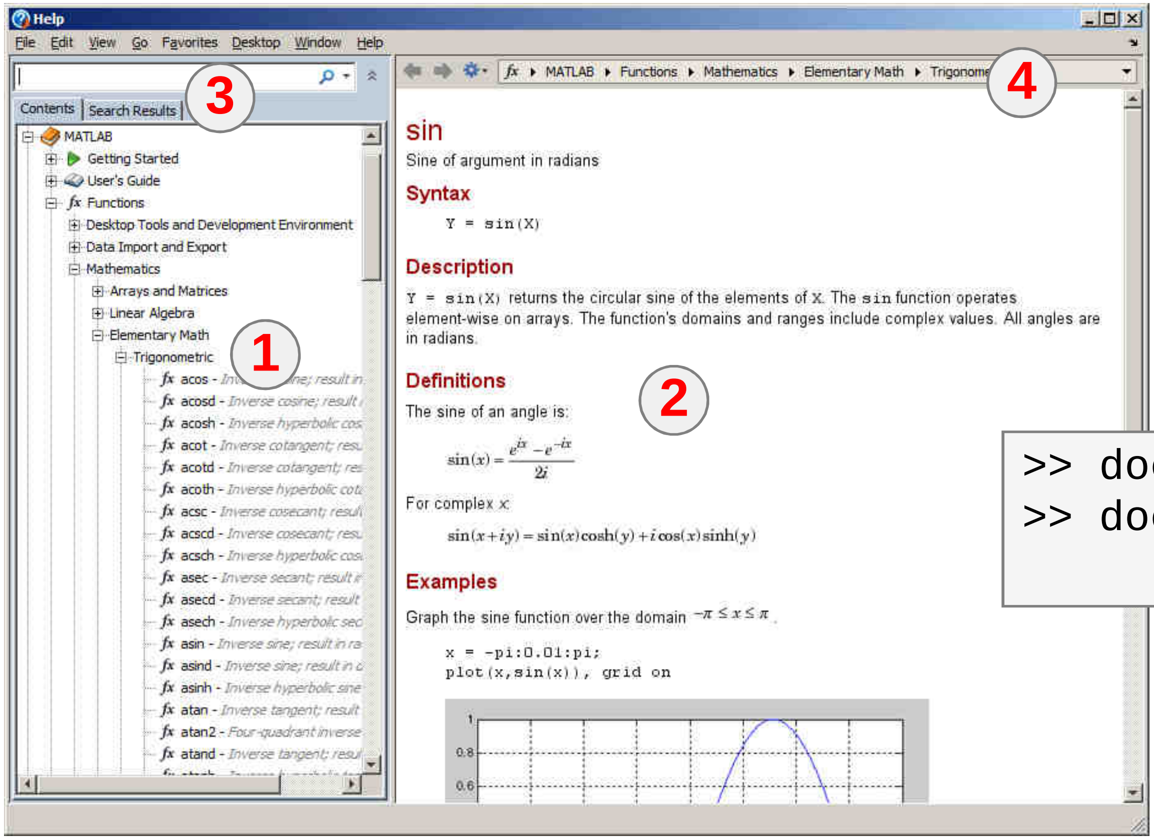


The Help structure, Matlab <R2011b



```
>> help 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

>>
```

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



Help
File Edit View Go Favorites Desktop Window Help
Contents
Search Results
MATLAB
Getting Started
User's Guide
Functions
Desktop Tools and Development Environment
Data Import and Export
Mathematics
Arrays and Matrices
Linear Algebra
Elementary Math
Trigonometric
acos - Inverse cosine; result in
acosd - Inverse cosine; result
acosh - Inverse hyperbolic cos
acot - Inverse cotangent; resu
acotd - Inverse cotangent; res
acoth - Inverse hyperbolic cot
acsc - Inverse cosecant; resul
acscd - Inverse cosecant; resu
acsch - Inverse hyperbolic cos
asec - Inverse secant; result i
asecd - Inverse secant; result
asech - Inverse hyperbolic sec
asin - Inverse sine; result in ra
asind - Inverse sine; result in d
asinh - Inverse hyperbolic sine
atan - Inverse tangent; result
atan2 - Four-quadrant inverse
atand - Inverse tangent; resul
MATLAB ▸ Functions ▸ Mathematics ▸ Elementary Math ▸ Trigonome
1
2
3
4
1
0.8
0.6

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.

Definitions

The sine of an angle is:

$$\sin(x) = \frac{e^{ix} - e^{-ix}}{2i}$$

For complex x:

$$\sin(x+iy) = \sin(x)\cosh(y) + i\cos(x)\sinh(y)$$

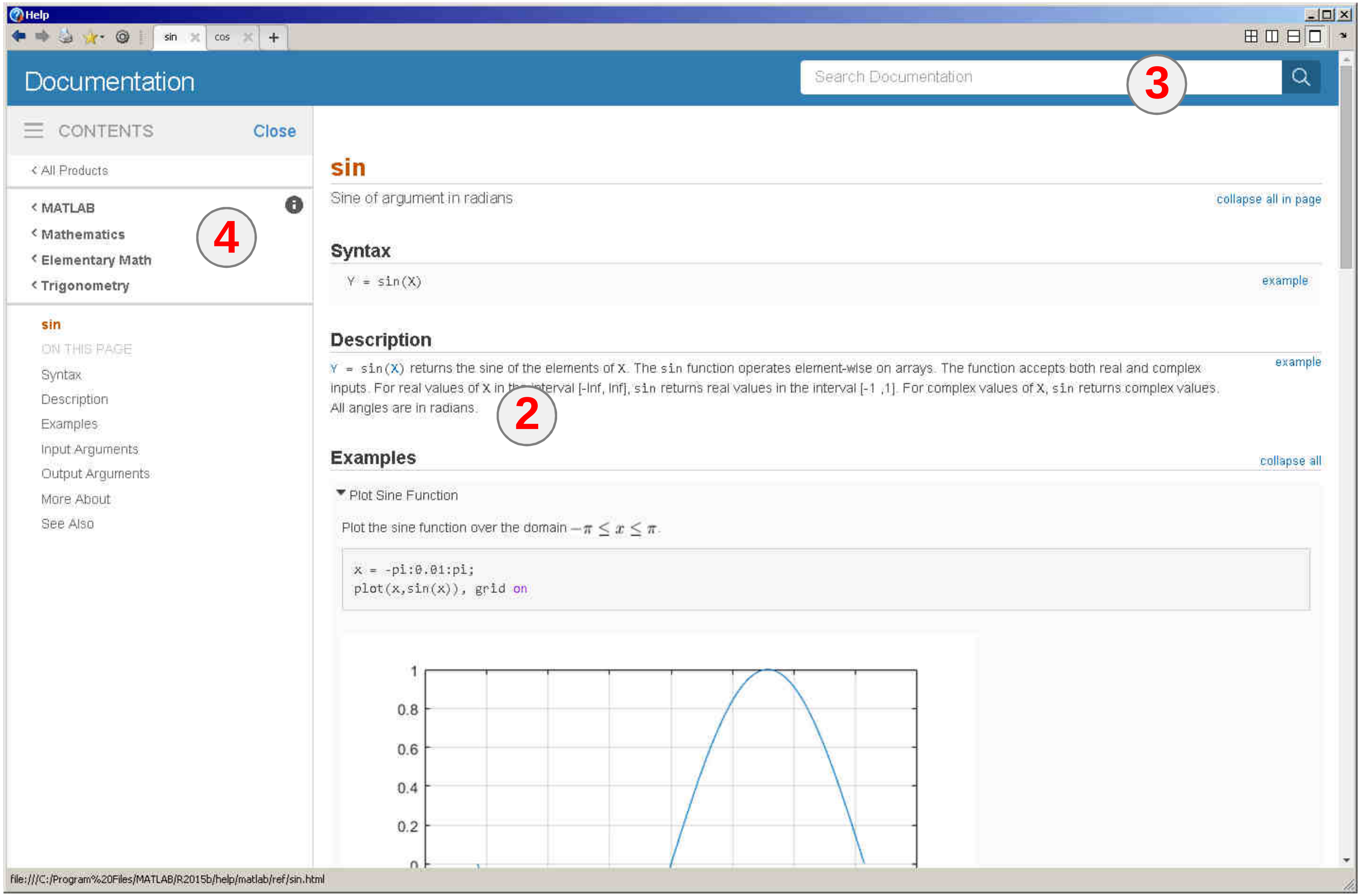
Examples

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

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

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

The Help structure, Matlab >R2011b



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sin
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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 in the interval [-Inf, Inf], `sin` returns real values in the interval [-1 ,1]. For complex values of X, `sin` returns complex values. All angles are in radians.

Examples

▼ Plot Sine Function

Plot 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%20Files/MATLAB/R2015b/help/matlab/ref/sin.html

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!

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