AE0B17MTB – Matlab

Part #8

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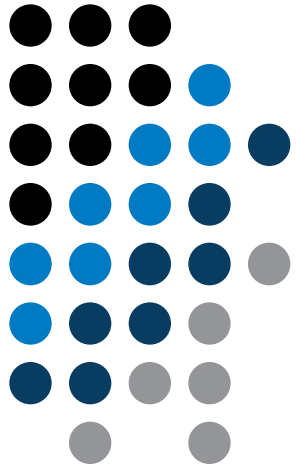


Learning how to …

Strings

`eval`, `feval`

Matlab `path`

Characters in Matlab

- string = array (a vector or a matrix or a cell) of characters
  - Try to avoid diacritics (accent) in Matlab
- string is created using apostrophes

```
>> st = 'Hello, world!'
```

  - strings are outputs of some functions (e.g. `>> char(65)`)
- each character in a string is an element of an array and requires 2 B
  - datatype `char`
- when an apostrophe is required to be part of a string, it is to be typed as two quote characters:

```
>> pt = 'That''s it!'
```

Strings in Matlab

- characters treated as strings (from R2016b): `string`

```
>> str = string(1);
>> str + 1 % = "11"
>> chr = char(1);
>> chr + 1 % = 2
```

  - unlike `char`, `string` does not treat numbers as ASCII or Unicode
  - string can be created by double quotes (from R2017a)

```
>> str = "a"
>> whos
```

- in the following both char and string are considered to be strings

Strings – principles

- in the case string has more than one line, it has to have same number of columns

```
>> st = ['george'; 'pepi  ']
```

- otherwise (usually) strings are stored as `cell` datatype:

```
pt = {'george', 'pepi', 'and all others', 'including accents ěščř'}
```

- whether a given variable is of type char is tested this way:

```
>> ischar(st)
>> iscellstr(pt)
```

Strings - type conversion

- quite often, it is required to convert from a number code to a string and vice versa, e.g.
  - `double` → `char`
  - `char` → `double`
  - `char` → `uint16`

```
>> tx = char([65:70])

>> B = double(tx)

>> C = uint16(tx)

>> whos
```

- operations with strings are similar to operations with numerical arrays
  - holds true for indexing in the first place!

```
>> S1 = 'test'; S2 = '_b5';
>> S3 = [S1 S2]
>> size(S3), size(S3')
>> S4 = [S3(3:5) 'end']
```

Strings

200 s ↑

- create an arbitrary string
  - find out its length
  - try to convert the string into double type
  - try to index selected parts of the string

- questions???

Strings – number conversion #1

- conversion of number in a string (`char`) to number (`double`):
  - conversion of multiple numbers (function `str2num`):

```
>> str2num('[1 2 3 pi]')
>> str2num('[1, 2;3 4]')
```

```
>> str2num('[1 2 3 pi]')

ans =

    1.0000    2.0000    3.0000    3.1416
```

```
>> str2num('[1, 2;3 4]')

ans =

     1     2
     3     4
```

  - conversion of a single number to `double` (`str2double`):

```
>> str2double('1 +1j')
>> str2double('-0.5453')
```

  - pay attention to possible errors that should be treated in the code

```
>> str2num('1a')
ans =
     []
```

```
>> str2num('1+1j')
```

```
>> str2num('1 +1j')
```

```
>> str2double('[1 2 3 pi]')
ans =
    NaN
```

```
>> str2num('1+1j')

ans =

   1.0000 + 1.0000i
```

```
>> str2num('1 +1j')

ans =

   1.0000 + 0.0000i   0.0000 + 1.0000i
```

Strings – number conversion #2

- quite often it is needed to convert numerical result back to a string

```
>> num2str(pi)
>> num2str(pi, 10)
```

```
>> disp(['the value of pi is: ' num2str(pi, 5)]);
```

- for listing purposes it is advantageous to use the function `sprintf`
  - it enables to control output format in a better way

```
>> st = sprintf('the value of pi is: %0.5f\n', pi);
>> st
```

Strings – other conversions

- among others there are other functions available

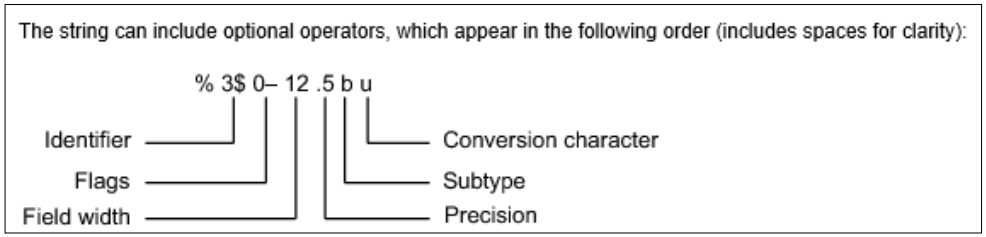
Function	Description
`int2str`	convert integer to text; in the case the input parameter is not an integer its value it is rounded first
`mat2str`	converts matrix to string
`hex2num, num2hex`	converts hexadecimal number of type `char` to a number (and vice versa)

- e.g.

```
>> mat2str(magic(3))
```

Strings – formatting

- function `sprintf` generates a string with given formatting
  - for more see `>> doc sprintf`
  - alternatively, `disp(sprintf(...))`



- function `fprintf` writes string
  - on a screen (`fid = 1` or `2`)
  - in a file (`fid` to be obtained e.g. using function `fopen`, see later)

```
>> st = sprintf('the value of pi is: %2.3e\n\n', pi);
>> fprintf(st) % or directly fprintf('...', pi);
```

```
>> fprintf(fid, st)
```

Strings

450 s ↑

- create following strings using `sprintf` help:
  - I.

```
ans =

Value of pi is: 3.14159, value of 5*pi is: 15.70796

>>
```

  - i.e. both numbers are displayed with five digits accuracy
  - II.

```
ans =

This is 50%



>>
```

  - i.e. display percent sign, the expression contains 3 line spacings
  - III.

```
ans =

This is a measurement set: test_A

>>
```

  - i.e. insert variable into the string, value of which is `'test_A'` string

Strings

200 s ↑

- think about the differences between `disp` a `fprintf (sprintf)`
  - describe the differences
  - what function do you use in a particular situation?

- function `fprintf (sprintf)`
  - it is faster with putting strings together
  - it offers significantly better formating options
  - it enables to work with functions like `warning`, `error`, …
  - standard function for file writing

Type conversion (general) – a note

- Matlab determines data types by itself
  - and also performs type conversion if needed

- single / double precission: `single()` / `double()`

- if, however, a particular data type is required that was not assigned on creation of a variable, this variable can by type-converted :
  - function `cast`: performs type conversion, values are truncated as the case may be
  - function `typecast`: performs type conversion and keeps the size of the original variable from the memory point of view as well as the bit value
  - see Matlab documentation for more

Upper case / lower case characters

- `lower` converts all letters in strings to lower case

```
>> lower('All will bE LOWERCASE')
% ans =
% all will be lowercase
```

- `upper` converts all letters in strings to upper case

```
>> str = 'all will be upper case';
>> str = upper(str)
% str =
% ALL WILL BE UPPER CASE
```

  - support of characters from Latin 1 character set on PCs
  - other platforms: ISO Latin-1 (ISO 8859-1)
  - $\Rightarrow$ supports Czech accents

Strings – searching

- `strfind` finds a given string inside another
  - returns indexes (positions)
  - searches for multiple occurrences
  - is CaSe sEnSiTiVe
  - enables to search for spaces etc.

```
>> lookFor = 'o';
>> res = strfind('this book', lookFor);
res =
     7     8
```

Strings – comparing

- two strings can be compared using function `strcmp`
  - the function is often used inside `if-else` / `switch-case` statements
  - the result is either `true` or `false`
  - it is possible to compare string vs. `cell` of strings or `cell` vs. `cell`

```
>> strcmp('tel', 'A')
>> strcmp('tel', 'tel')
>> strcmp('test', {'test', 'A', '3', 6, 'test'})
>> strcmp({'A', 'B'; 'C', 'D'}, {'A', 'F'; 'C', 'C'})
```

$$\left(\begin{bmatrix} A & B \\ C & D \end{bmatrix} == \begin{bmatrix} A & F \\ C & C \end{bmatrix} \right) = \begin{bmatrix} 1 & 0 \\ 1 & 0 \end{bmatrix}$$

Strings – joining

- strings can be joint together using function `strjoin`
  - it as applicable to variables of type `cell`
  - separator is optional (implicitly a space character)

```
>> cl = {'A', 'B', 'C', 'D'}
>> strjoin(cl)
>> strjoin(cl, ',')
```

```
>> cl = {'A','B','C','D'}

cl =

    'A'    'B'    'C'    'D'

>> strjoin(cl)

ans =

A B C D

>> strjoin(cl,',')

ans =

A,B,C,D
```

- `fullfile` connects individual folders into a file path
  - back slash (\) is inserted between individual items (Win)

```
>> folder1 = 'Matlab';
>> folder2 = 'project_one';
>> file    = 'run_process.m';
>> fpath = fullfile(folder1, folder2, file);
```

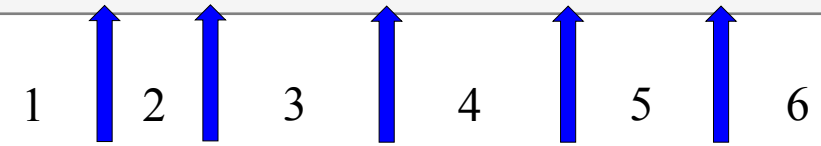
```
fpath =

Matlab\project_one\run_process.m
```

  - replace invalid separator depending on platform
  - will be used for exporting and work with GUI

Strings – string separation

- function `deblank` removes excess space characters from end of string
- function `strtrim` removes space characters from beginning and end of string
- if a string is to be split, function `strtok` is used
  - separator can be chosen arbitrarily

```
>> this_str = 'some few little little small words'
```




```
>> [token, remain] = strtok(this_str, ' ');
```

first separated word

rest of string

Strings – string separation

- function `regexp` enables to search a string using regular expressions
  - syntax of the function is a bit complicated but its capabilities are vast!!
    - Ex.: search for all words beginning with '`wh`' with vowels `a` or `e` after and containing 2 characters:

```
>> that_str = 'what which where whose';
>> regexp(that_str, 'wh[ae]..', 'match')
```

    - Ex.: search indexes (positions) where words containing `a` or `o` begin and end

```
>> that_str    = 'what which where whose';
>> [from, to] = regexp(that_str, '\w*[ao]\w*')
```

  - for more details see `>> doc regexp` → `Input Arguments`
  - in combinantion with above mentioned functions, typical tokenizer can be created

Strings

600 s ↑

- try out following commands and try in advance to estimate what happens …

```
>> str2num('4.126e7')
>> str2num('4.126A')
>> D = '[5 7 9]';
>> str2num(D)
>> str2double(D)
>> int2str(pi + 5.7)
>> A = magic(3);
>> mat2str(A)
>> disp([15 pi 20-5i]);
>> disp(D);
>> B = 'MaTLaB';
>> lower(B)
```

```
>> C = 'cik cak cet  ';
>> strfind(C, 'cak')
>> deblank(C)
>> [tok remain] = strtok(C, ' ')
>> [st se] = regexp(C, 'c[aeiou]k')
>> [st se] = regexp(C, 'c[ei][kt]')
>> regexp(C, '[d-k]')
>> fprintf('Result is %3.7f', pi);
>> fprintf(1, 'Enter\n\n');
```

```
>> disp([' Result: ' num2str(A(2, 3)) 'mm']);
>> fprintf(1, '% 6.3f%% (per cent)\n', 19.21568);
>> fprintf('Will be: %3.7f V\n', 1e4*(1:3)*pi);
>> fprintf('A=%3.0f, B=%2.0f, C=%1.1f\n', magic(3));
>> fprintf('%3.3e + %3.3f = %3.3f\n', 5.13, 13, 5+13);
>> fprintf(2, '%s a %s\n\n', B, C([1:3 5:7]));
```

Strings – comparing

300 s ↑

- function to compare strings (CaSe SeNsItIvE) is called `strcmp`
  - try to find a similar function that is case insensitive
  - try to find a function that is analogical to the above one (i.e. case insensitive), but compares first `n` characters only
  - think about alternatives to the `strcmp` function

Strings

300 s ↑

- remove all blank spaces from the following string
  - try to recollect logical indexing
  - or use an arbitrary Matlab function

```
>> s = 'this is a big book'
```

- utilization of position of blank space in ASCII table

Strings

420 s ↑

- write a script/function that splits following sentence into individual words using `strtok`
  - display number of occurrence of string `'is'`
  - list the words individually including position of the word within the sentence (use `fprintf`)

```
clear; clc;
sen    = 'This-sentence-is-for-testing-purposes-only.';
...
...
...
...
...
...
...
...
```

Strings

420 s ↑

- write a script/function that splits following sentence into individual words
- the problem can be solved in a more elegant way using function `textscan`
  - solution, however, is not complete (word order is missing)

`eval` – string as a command

- motivation:

```
>> st  = 'sqrt(abs(sin(x).*cos(y)))';
>> x   = 0:0.01:2*pi;
>> y   = -x;
>> fxy = eval(st);
>> plot(x, fxy);
```

  i.e. there is a string containing executable terms
  - its execution is carried out by function `eval`
- applicable mainly when working with GUI (execution of commands entered by user, processing callback functions etc.)
- `eval` has certain disadvantages, therefore its usage is a matter of consideration:
  - block of code with `eval` is not compiled (slow down)
  - text inside the string can overwrite anything
  - syntax inside the string is not checked, it is more difficult to understand
- see function help for cases where it is possible to replace `eval`
  - e.g. storing files with serial number (`data1.mat`, `data2.mat`, …)

evalc

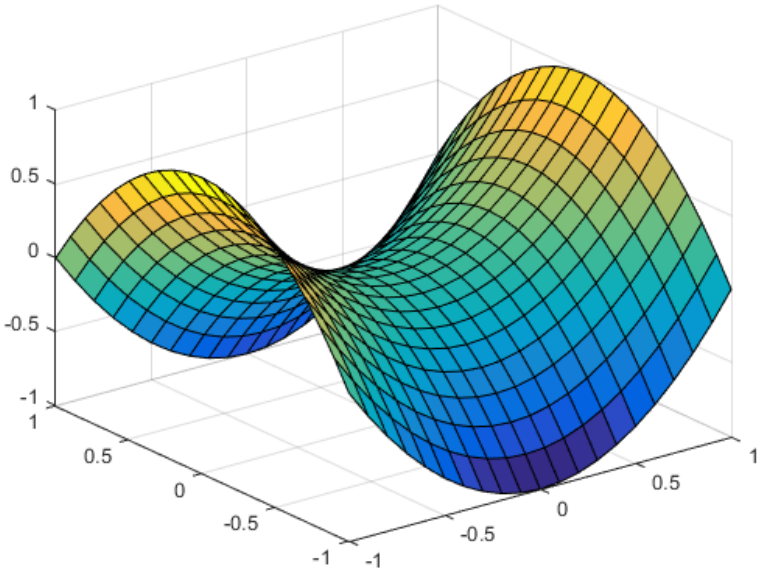
- in some cases it is needed not only to carry out a command in form of a string but also to store the result of the command for later use
- function `evalc` („*eval with capture*“) serves this purpose

```
>> CMD = evalc(['var = ' num2str(pi)]);
>> CMD

CMD =


var =

    3.1416



>> whos
  Name       Size              Bytes  Class     Attributes

  CMD        1x20                 40  char
  var        1x1                   8  double
```

`feval` – evaluation of a handle function

- the function is used to evaluate handle functions
  - simply speaking, where `eval` evaluates a string there `feval` evaluates function represented by its handle
  - consider this task:

$$f(x,y) = x^2 + y^2, \quad x, y \in \langle -1, 1 \rangle$$




```
>> hFcn    = @(x,y) x.^2 - y.^2;
>> x       = -1:0.1:1;
>> y       = x;
>> [X, Y] = meshgrid(x, y);
```

```
>> fxy     = hFcn(X, Y);
>> surf(X, Y, fxy);
```

```
>> fxy     = feval(hFcn, X, Y);
>> surf(X, Y, fxy);
```

Newton's method – modification

600 s ↑

- modify former Newton's method applied to finding root of a polynomial in the way that the polynomial is entered in the form of a handle function
  - see `cw.fel.cvut.cz/wiki/courses/a0b17mtb/start` → week 8
  - verify the code by finding roots of following polynomials :

$$x - 2 = 0, \quad x^2 = 1$$

  - verify the result using function `roots`

Function `exist`

- the function finds out whether the given word corresponds to existing
  (=1) variable in Matlab Workspace
  (=5) built-in function
  (=7) directory
  (=3) mex/dll function/library
  (=6) p-file
  (=2) m-file known to Matlab (including user functions, if visible to Matlab)
  (=4) mdl-file
  (=8) class
  (in the order of priority, return value in bracket)

```
>> type = exist('sin')    % type = 5
>> exist('task1', 'var')   % is the file task1 ...
>> exist('task1', 'dir')   % a variable / ...
>> exist('task1', 'file') % directory / file?
```

What does your m-file depend on?

- in the case you compile your code, send it to colleagues etc., it is suitable to test whether they have all files and functions required
- function `matlab.codetools.requiredFilesAndProducts`
  - return user files and products necessary for evaluation of function/script
  - does not return files which are part of required products
- Ex.: dependencies of Newton's Method script

```
>> [fList, plist] = ...
matlab.codetools.requiredFilesAndProducts('newton_method_start.m')

fList =

    'D:\MTB\newton_method_start.m'    'D:\MTB\optim_fcn.m'


plist =

             Name: 'MATLAB'
          Version: '8.6'
    ProductNumber: 1
          Certain: 1
```

How to create a function – tips

- how to indicate that the given function / script is running?
  - try several possibilities below…

```
fprintf('START\n    ');
for n = 1:100
    fprintf(1, '\b\b\b\b%3.0f%%', n);
    pause(0.05);
end
fprintf('\nEND\n');
```

```
T = ['/' '-' '\'];
fprintf(2, 'START\n\n');
for n = 1:100
    fprintf(1, '\b%c', T(mod(n, 3)+1));
    pause(0.05);
end
fprintf('\b');
fprintf(2, 'END\n');
```

```
fprintf(2, 'START\n');
for n = 1:100
    fprintf(1, '*');
    pause(0.05);
end
fprintf(1, '\n');
fprintf(2, 'END\n');
```

  - later we will see graphical options as well!

Matlab – file suffix

suffix	description
`.m`	script / function / class
`.mdl, .slx`	Simulink model
`.mexa64, .mexmaci64, .mexw32, .mexw64`	mex libraries
`.mlpkginstall`	support package – installer
`.mn`	MuPAD notebook
`.p`	protected Matlab code

Discussed functions

`char, uint16, ...`	type conversion / creation of variables of given type	●
`single, double`	single / double precision	
`ischar, iscellstr`	test if input is character array / cell array of strings	
`int2str, mat2str, hex2num, num2hex`	conversion (integers – strings, hexadecimal – IEEE double)	
`str2double`	string to double	
`sprintf, fprintf`	String formatting, write to text file	●
`cast, typecast`	type conversion (not keeping / keeping underlying size)	
`lower, upper`	convert string to lowercase / uppercase	
`strfind, strcmp, strjoin, fullfile`	search, compare, join strings	●
`deblank, strtrim, strtok`	remove blank spaces, remove leading and trailing space, split string	●
`regexp, textscan`	search string (including regular expressions)	●
`eval, feval`	evaluate string / evaluate handle function	●
`path, exist`	view or change search path, check existence of variable	

Exercise #1, #2

450 s ↑

- find out how many spaces there are in the phrase „*how are you?*“
  - look in this lecture / help and find out a suitable function
  - utilize logical indexing
- convert following string to lowercase and find number of characters

```
>> st = 'MATLAB is CaSe sEnSiTiVe!!!';
```

Exercise #3

300 s ↑

- create a function to calculate volume, surface area and space diagonal of following bodies: cuboid, cylinder
  - the main function `main.m` contains verification of input variables (type, size) and checking whether user wants to calculate cuboid (parameters `'cuboid', a, b, c`) or cylinder (`'cylinder', r, h`)
- sub-functions `cuboid()` and `cylinder1()` calculate required parameters

```
function [V, S, u] = main(gType, a, b, c)
% decision making
% call functions
end

function [V, S, u] = cuboid(a, b, c)
% ... code
end

function [V, S, u] = cylinder1(r, h)
% ... code
end
```

Exercise #3

```
...
...
...
...
...
...
...
...
...
...
...
...
...
...
...
...
...
% ... continuation
```

```
% ... continuation

...
...
...
...
...
...
...
...
...
...
...
...
```

Exercise #4

600 s ↑

- create so called tokenizer (text analyzer), that
  - reads a text input `str` entered by user using function `input`
  - reads separator `sep` (attention, space requires some care!!)
  - split `str` in individual parts depending on `sep`
  - store individual parts separately in a variable of type `cell`
  - analyze how many vowels (a/e/i/y/o/u) each individual word contains, store this number and display it together with list of all individual words
  - all commands in the whole script / function have to be terminated with a semicolon!

Exercise #4

- create a tokenizer (text analyzer)
  - solution using `strtok`

```
...
...
...
...
...
...
...
...
...
...
...
...
...
...
...
...
...
...
```

Exercise #4

- improved solution using `strsplit`

Exercise #5

600 s ↑

- try to create simple unit convertor, length `x` is given in `'mm'`, `'cm'`, `'in'`, `'inch'` (variable `units`), length in inches can be marked as `'in'` or `'inch'`. Length will be transformed into [mm] according to entered unit string.
  - what decision making construct are you going to use?
  - add a statement from which unit the length was converted and what the result is

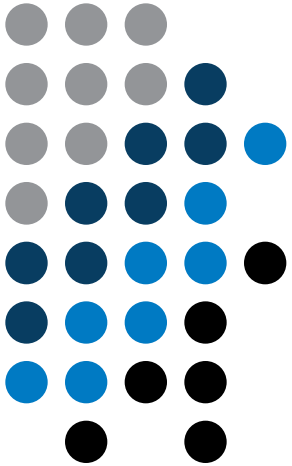
```
x     = 15;
units = 'in';
% add the rest
```

Exercise #5

Unit conversion – more elegant way

- use data type `struct` and its properties
  - individual arrays in the structure can be indexed using variables of type `char`

Thank you!



ver. 8.1 (12/11/2017)
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