Lecture 6: Data Types: Cell, String, and Structure

B0B17MTB, BE0B17MTB – MATLAB

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Outline

Class `cell`

- Variable of class `cell` enables to store all types of variables of various dimensions (*i.e.*, for instance variable of type cell inside another variable of type cell).
- Example of a cell:

```
CL1 = {zeros(2), ones(3), rand(4), 'test', {nan(1), inf(2)}};
```

- Variable of the class `cell` can be easily allocated:

```
CL2 = cell(1, 3);
```

- Memory requirement is a trade-off for complexity of cell type.
- Typical applications of cells:
  - in `switch-case` branching for enlisting more possibilities,
  - variously long vectors of characters,
  - graphical user interface (GUI),
  - all iteration algorithms with variable size of variables,
  - packing of name-value arguments,
  - ...

Cell Indexing I.

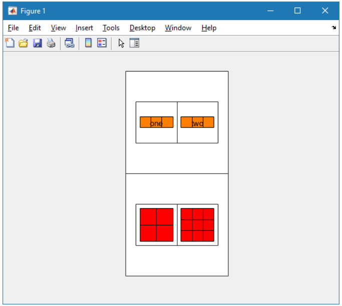
- There are two possible ways of cell structure indexing:
  - round brackets `( )` are used to access cells as such,
  - curly brackets `{ }` are used to access data in individual cells.
  - Example:

```
CL = {[1, 2; 3, 4], eye(3), 'test'};
CL(2:3)        % returns cells 2 and 3 from CL
CL{1}          % returns matrix [1 2; 3 4]
CL{1}(2, 1)   % = 3

CL3 = CL(1)   % CL3 is cell
M   = CL{1}   % M is a matrix of numbers of type double
```

Cell Indexing II.

- Example of more complicated indexing:
- Functions to get oriented in a cell:
  - `celldisp`,
  - `cellplot`.




```
CL4 = {'one', 'two'};
CL5 = {[1, 2; 3, 4], magic(3)};
CL6 = {CL4; CL5}
CL6{2}{1}(2, 1)   % = 3
```

```
>> celldisp(CL6)
CL6{1}{1} =
one
CL6{1}{2} =
two
CL6{2}{1} =
    1    2
    3    4
CL6{2}{2} =
    8    1    6
    3    5    7
    4    9    2

>> cellplot(CL6)
```

Data Types

cellfun

- Apply function to each cell in cell array
  - `A = cellfun(func, C)` returns array `A` so that `A(i) = func(C{i})`,
  - function can be defined as anonymous or a handle,
  - reduces the need for `for` loops in the code.
  - Example:

```
CL = {zeros(3), magic(4); diag(1:5), rand(6)};
nElements = cellfun(@numel, CL)
% OR:
nElements = cellfun(@(x)numel(x), CL)
nColumns = cellfun(@(x)size(x, 2), CL)
maxVal = cellfun(@(x)max(x(:)), CL)
% OR:
maxVal = cellfun(@(x)max(x, [], 'all'), CL)
```

- When returned variable cannot be concatenated into an array:

```
firstColumns = cellfun(@(x)x(:, 1), CL, 'UniformOutput', false)
```

Data Types

Strings I.

- Strings in MATLAB can be represented in two forms:
  - As a vector of characters which are represented as `char` data type.
  - It is created using apostrophes:

```
st1 = 'Hello world!';
```

  - As `string` data type.
  - The whole sentence is `string` scalar.
  - It is created using double quotes:

```
st2 = "Hello world!";
```

```
>> whos
Name      Size            Bytes  Class     Attributes
st1       1x12               24  char
st2       1x1               150  string
```

- Distinguish between:
  - "string" in meaning of text and
  - "`string`" as data type.
- Most of the functions work with both string types.
- Try to avoid diacritics (accent) in MATLAB.

Strings – Class char

- Characters are outputs of some functions (*e.g.*, `char([89, 69, 83, 33])`, `blanks(5)`).
- Each character (each element of array) requires 2 B.
- If an apostrophe is required to be part of a string, it is to be typed as two quote characters:

```
st3 = 'That''s it!'
```

- In the case of more lines of characters, it has to have same number of columns:

```
st4 = ['george'; 'pepi  '];
size(st4) % [2, 6]
```

- Otherwise (usually), character arrays are stored in `cell` data type:

```
st5 = {'george', 'pepi', 'and all others', 'are good boys.'};
```

- Whether a given variable is of class `char` is tested this way:

```
ischar(st4)    % true
ischar(st5)    % false
iscellstr(st5)  % true
```

Strings – Class `string`

- Allocation using function `strings` enables to create empty strings:

```
str1 = strings
str2 = strings(3)
str3 = strings(5, 1)
```

- Unlike `char`, `string` does not treat numbers as ASCII or Unicode.
  - When comparing `string` and `char`, type conversion is performed.

```
>> 'a' + 1
ans =
   98
```

```
>> "a" + 1
ans =
   "a1"
```

```
>> "a" < 'b'
ans =
  logical
   1
```

```
>> 'a' == 97
ans =
  logical
   1
```

```
>> "a" == 'a'
ans =
  logical
   1
```

- `strings` can be easily stored in a vector:

```
stringArray = ["a", "something", "long string"]
```

```
stringArray =
  1x3 string array
    "a"    "something"    "long string"
```

- `string` class offer many functions for a text analysis.

Data Types

Strings – Type Conversion

- Quite often, it is required conversion between numbers, characters, strings and cells.
- Conversions:

```
V = [116, 101, 120, 116];
CH = 'text';
ST = "text";
CL = {'t', 'e', 'x', 't'}
```

from\to	**numeric**	**char**	**string**	**cell**
numeric	—	`char(V)`	`string(char(V))`	`num2cell(char(V))`
char	`double(CH)`	×	`string(CH)`	`num2cell(CH)`
string	`double(char(ST))`	`char(ST)`	×	`num2cell(char(ST))`
cell	`double([CL{:}])`	`char(CL)'`	`join(string(CL), '')`	×

Data Types

Strings – Indexing

- Indexing in arrays of characters is the same as with a numerical arrays.
- Indexing in arrays of strings returns the whole `string` objects.
- Example:

```
CH1 = ['Text!!', 'string'];
CH2 = ['Hello?', 'Matlab'];
CH = [CH1; CH2];
size(CH), length(CH)
CH'
CH(1:2, 1)
CH(:)
CH(1:3:end)
```

```
ST1 = ["Text!!", "string"];
ST2 = ["Hello?", "Matlab"];
ST = [ST1; ST2]
size(ST), length(ST),
strlength(ST)
ST'
ST(1:2, 1)
ST(:)
ST(1:3:end)
```

- Indexing in `strings` in the same manner as in `chars` requires functions:

```
CH1([2:4])
CH1(8:end)
CH1(1:5)
```

=

```
extractBetween(ST1(1), 2, 4)
extractAfter(ST1(2), 1)
extractBefore(ST1(1), 6)
```

Data Types

Strings – Number Conversion I. – char

- Conversion of number represented as a string (char) to number (double):
  - Conversion of multiple numbers (function str2num):

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

```
>> str2double('-0.5453')
```

- Pay attention to possible errors:

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

Data Types

Strings – Number Conversion II. – string

- Conversion of number in a string (string) to number (double):
  - Same functionality as with char:

```
>> a = "[1 2 3e-2 pi]";
>> [num, conf] = str2num(a)
num =
   1.0000   2.0000   0.0300   3.1416
conf =
  logical
   1
>> str2double(a)
ans =
   NaN
>> str2double("-2.35")
ans =
    -2.3500
```

Data Types

Strings – Number Conversion III.

- Quite often is needed to convert numerical results back to a string:

```
num2str(pi);     % '3.1416'
num2str(pi, 10); % '3.141592654'
string(pi);      % "3.1416"
```

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

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

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

  - See below. . .

Data Types

Strings – Other Conversions

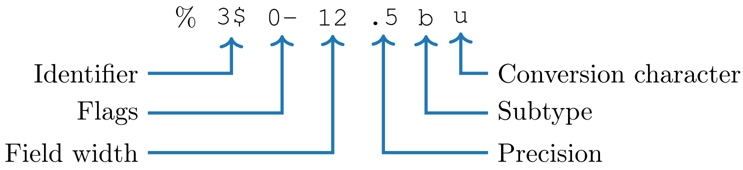
- Among others there are other functions available.

Function	Description
`int2str`	Convert integer to text. In the case the input parameter is not an integer, its value is rounded first.
`mat2str`	Converts matrix to string.
`hex2dec`, `dec2hex`	Converts hexadecimal number of type `char` to a number (and vice versa).

```
>> mat2str(magic(3))
ans =
   '[8 1 6;3 5 7;4 9 2]'
>> mat2str(eye(2))
ans =
   '[1 0;0 1]'
>> hex2dec('B')
ans =
   11
```

Strings – Formatting

- Function `sprintf` generates a string with given forrmatting.
  - For more see >> `doc sprintf`
  - Alternatively, `disp(sprintf(..))`



- Function `fprintf` writes string:
  - on a screen (`fid = 1` for black text, `fid = 2` for red text),
  - in a file (`fid` to be obtained using function `fopen`, more on later).

```
st = sprintf("The value of pi is %2.3e\n", pi);
fprintf(st)
```

```
fprintf('The value of pi is %2.3e\n', pi);
```

Strings I.

- Create following strings using `sprintf` help:
  - A)

```
sprintf(..) % update the argument
```

```
ans =
   'Value of pi is 3.14159, value of 5*pi is 15.70796.'
```

  - B)

```
x = 50;
```

```
sprintf(..) % update the argument
```

```
ans =
   'This is 50%'
```

  - C)

```
tx = 'test_A';
```

```
sprintf(..) % update the argument
```

```
ans =
   'This is a measurement set: test_A'
```

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Strings I.

- Create following strings using `sprintf` help:
  - A)

```
ans =
   'Value of pi is 3.14159, value of 5*pi is 15.70796.'
```

  - B)

```
x = 50;
```

```
ans =
   'This is 50%'
```

  - C)

```
tx = 'test_A';
```

```
ans =
   'This is a measurement set: test_A'
```

Strings II.

- Think about differences between `disp` and `fprintf` (`sprintf`).
  - Describe the differences.
  - What function do you use in a particular situation?

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Lower Case / Upper Case Characters

- Lower / upper conversion for `char` class:

```
st = 'RanDOMLy SizeD LeTTErs';
lower(st) % result = 'randomly sized letters'
upper(st) % result = 'RANDOMLY SIZED LETTERS'
```

- Lower / upper conversion for `string` class:

```
st2 = "RanDOMLy SizeD LeTTErs";
lower(st2); st2.lower % result = "randomly sized letters"
upper(st2); st2.upper % result = "RANDOMLY SIZED LETTERS"
```

- Support of characters from Latin 1 character set on PCs.
- Other platforms: ISO Latin-1 (ISO 8859-1).
- Supports Czech accents.

Strings – Joining

- Strings can be joint together using function `strjoin` and `join`.
  - It is applicable to variables of type `cell` and `string`.
  - Separator is optional (implicitly a space character)

```
CL = {'Once', 'upon', 'a', 'time'};
strjoin(CL) % 'Once upon a time'
strjoin(CL, '\n')
join(CL) % {'Once upon a time'}
join(CL, '\') % {'Once\upon\a\time'}
```

```
ST = ["Once", "upon", "a", "time"];
strjoin(ST) % "Once upon a time"
strjoin(ST,'\b')% backsp., "Oncupotime"
join(ST) % "Once upon a time"
join(ST, '_') % "Once_upon_a_time"
```

- Function `fullfile` connects individual inputs into a file path.
  - The separator depends on the platform (Win, Linux, Mac, ...).

```
folder1 = 'Matlab';
folder2 = 'project1';
file = 'run_process.m';
fpath = fullfile(folder1, folder2, file);
% fpath = 'Matlab\project1\run_process.m'
```

Data Types

Strings – Separation I.

- 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 arbitrary.

```
this_str = 'some few little little small words';
[token, remain] = strtok(this_str, ' ');
```

Data Types

Strings – Separation II.

- Function `regexp` enables to search a string using regular expressions.
  - Syntax of the function is a bit complicated but its capabilities are vast!
  - Example: 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')
```

  - Example: Search indices (positions) where words containing `'a'` or `'o'` begin begin and end.

```
[from, to] = regexp(that_str, '\w*[ao]\w*');
```

  - For more details see >> `doc regexp` → Input Arguments.
  - Typical tokenizer can be created in combination with above mentioned function.

Data Types

Strings – Searching

- Function `contains` determine if pattern is in string:

```
str = ["Mary Ann Jones", "Christopher Matthew Burns", "John Paul Smith"];
contains(str, ["ann", "paul"], 'IgnoreCase', true) % logical [1 0 1]
```

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

```
str = 'This book is about history';
res = strfind(str, 'is'); % [3, 11, 21]
```

```
str2 = ["The Exakta 66 was based on the Pentacon Six but was made in West Germany.", ...
  "From January 1985 a monthly production of 200 cameras was planned."];
strfind(str2, 'was') % {[15 49]}   {[55]}
```

Data Types

Strings III.

- Remove all blank spaces from the following sentence[1].

```
s = 'Do what you can, with what you have, where you are.'
```

  - Try to recollect using logical indexing,
  - or use proper MATLAB function.

- Calculate how many times `'you'` is used.

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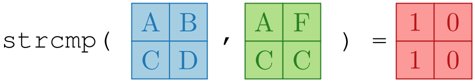
[1] Theodore Roosevelt

Strings – Comparing I.

- Two strings can be compared using function `strcmp`.
  - The function is often used inside `if` or `switch` statements.
  - The result is either `true` or `false`.
  - It is possible to compare `string`, `char` and `cell` of strings.

```
strcmp('tel', 'A') % = 0
strcmp("tel", 'tel') % = 1
strcmp(["tel", 5], '5') % = 1
strcmp('test', {'test', 'A', '3', 6, 'test'})      % = [1, 0, 0, 0, 1]
strcmp('test', ["test", "A", "3", 6, "test"])      % = [1, 0, 0, 0, 1]
strcmp({'A', 'B'; 'C', 'D'}, ["A", "F"; "C", "C"]) % = [1, 0; 1, 0]
strcmp({'A', 'B'; 'C', 'D'}, {'A', 'F'; 'C', 'C'}) % = [1, 0; 1, 0]
```



Strings – Comparing II.

- Function to compare strings (CaSe SeNsItIvE) is called `strcmp`.
  - Try to find a similar function that is case insensitive.

```
strcmpi(string1, string2)
```

  - Try to find a function that is analogical to the above one (*i.e.*, case insensitive) but compares first n characters only.

```
strncmpi(string1, string2, n)
```

  - Think about alternatives to the `strcmp` function.

```
isequal(string1, string2)
all(string1 == string2)
```

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Strings IV.

- 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]));
```

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Strings V.

- 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`).

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

```
remain = sen;
word   = 1;
while ~isempty(remain)
   [token, remain] = strtok(remain, '-');
   fprintf('%2.0f. word is: %s\n', word, token);
   word = word + 1;
end
fprintf('The string ''is'' is used %2.0fx.\n', length(strfind(sen, 'is')));
```

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Strings VI.

- 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).

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

```
Tokens = textscan(sen, '%s', 'delimiter', '-');
celldisp(Tokens);
fprintf('The string ''is'' is used %2.0fx.\n', length(strfind(sen, 'is')));
```

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Function vs. Command Syntax

- In MATLAB exist two basic syntaxes how to call a function.

```
>> grid on    % Command syntax
>> grid('on') % Function syntax
```

```
>> disp 'Hello World!'   % Command syntax
>> disp('Hello World!') % Function syntax
```

- Command syntax:
  - All inputs are taken as characters.
  - Outputs can't be assigned.
  - Input containing spaces has to be closed in single quotation marks.

```
>> a = 1; b = 2;
>> plus a b % = 97 + 98
ans =
  195
>> p = plus a b % error
>> p = plus(a, b);
```

Code Execution

Function `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`.
  - Example storing files with serial number (`data1.mat`, `data2.mat`, ...).

String to Function, Function to String

- It is possible to construct function handle from string/character array using `str2func` function.
- The usage is in some case similar to `eval`.
  - Difference is, that `str2func` does not see variables outside the local workspace and nested functions.

```
sin = 10;
str = '@(x) sin(x)';
f1 = eval(str);
f2 = str2func(str);
```

```
f1(1)
ans =
   10
f2(1)
ans =
   0.8415
```

- Funciton `func2str` is used to transform function handle to character array.

```
func2str(f1)
ans =
   '@(x)sin(1)'
```

Function 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 =
   'var = 3.1416'
>> var
var =
   3.1416
```

Function feval – Evaluation of a Handle Function

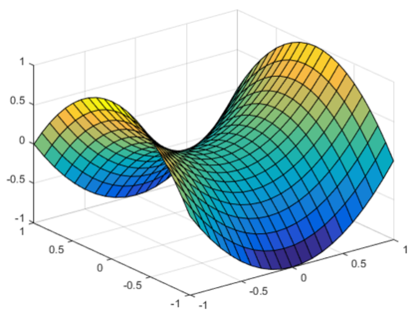
- The function is used to evaluate handle functions.
  - Simply speaking, where `eval` evaluates a string there `feval` evaluates function represented by its handle.
  - Consider this task:

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

```
hFcn   = @(x,y) x.^2 - y.^2;
X      = -1:0.1:1;
Y      = X.';
```

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

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



Scripts and Functions

Function `exists`

- The function `exists` 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 defined functions, if visible to MATLAB),
  - =4 mdl-file,
  - =8 class.
  - Sorted in the order of priority, returned value in bracket.

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

Scripts and Functions

Reading Binary Data From a File

- Useful functions to read binary data from a file:
  - `fopen` – open the file and return the reference.
  - `fgetl` – read one line from the file, removing newline characters.
  - `fgets` – read one line from the file, keeping newline characters.
  - `feof` – test for the end of file.
  - `fclose` – close the file. Always close the file!

```
fid = fopen('sin.m');
while ~feof(fid)
   thisLine = fgetl(fid);
   disp(thisLine);
end
fclose(fid);
```

Writing Data to a File

- Use `fprintf` to write a line into a file.
- It is necessary to open the file with permission for writing: `'w'`.
- Use `'\n '` to indicate new line in `fprintf` command.

```
fid = fopen('myData.txt', 'w');
D = rand(5, 3);
fprintf(fid, 'My Measured data:\n');
for iLine = 1:size(D, 1)
   fprintf(fid, '%1.4f, %1.4f, %1.4f\n', D(iLine, :));
end
fclose(fid)
```

Save Data in ASCII Format I.

- `writematrix` writes single numeric or string array variable into a file.
  - Supports .txt, .dat, .csv, .xlsx, ... formats,
  - numeric data saves in double precision,
  - multidimensional array is reshaped to 2D matrix.

```
data = reshape(1:2*3*4, 2, 3, 4);
writematrix(data) % data.txt file created
```

```
>> type('data.txt') % show content of data.txt

1,3,5,7,9,11,13,15,17,19,21,23
2,4,6,8,10,12,14,16,18,20,22,24
```

- `readmatrix` read single array of numeric or string data.
  - Wide range of read settings (headlines, delimiters, comments, decimal separator, ...).

```
dataR = readmatrix("data.txt");
dataR = reshape(dataR, 2, 3, 4);
```

Save Data in ASCII Format II.

- It is possible to save data in standardized ASCII format using function `save` with `'-ascii'` argument.

```
p = rand(1,5);
q = ones(3);
save('pqfile.txt','p','q','-ascii')
```

- The content of `pqfile.txt`

```
4.9836405e-01  9.5974396e-01  3.4038573e-01  5.8526775e-01  2.2381194e-01
1.0000000e+00  1.0000000e+00  1.0000000e+00
1.0000000e+00  1.0000000e+00  1.0000000e+00
1.0000000e+00  1.0000000e+00  1.0000000e+00
```

variable p

variable q

Variables Storing and Loading

- Existing variables in MATLAB workspace can be stored on disk.

```
>> a = 1; b = 2; c = magic(5);
>> save % stores all variables in matlab.mat in current folder
>> save task1 % stores all variables in task1.mat
>> save task1 a b c % stores variables a, b and c in task1.mat
```

- The shortcut `CTRL + S` in Command window or Command history can be used.
- Loading variables is analogical.

```
>> load % loads matlab.mat in current folder
>> load task1 % loads all variables from task1.mat
>> load task1 a b c % loads variables a, b and c from task1.mat
```

  - Alternatively, drag&drop the file from Current folder to Command window can be applied.

String to Function, Function to String

- Implement script/function that:
  - creates anonymous function $\mathbf{M}(x) = [\sin(x)\ \cos(x)]$,
  - saves this anonymous function in form of string into a text file (`*.txt`),
  - loads string from file and transforms it into anonymous function,
  - evaluates anonymous function for $x = 1$.

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Indication of Running Function/Script

- How to indicate that given function/script is running?
  - Try these several possibilities ...

```
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!

Structured Variable, `struct`

- Data can be stored in a grouped form in structures.
- Concept is similar to OOP (without features of OOP).
- Example: inventory

```
stock.id = 1;
stock.thing = "fridge";
stock.price = 750;
stock(2).id = 2;
stock(2).thing = "Bowmore_12yr";
stock(2).price = 1100;
```

- or:

```
stock = struct('id', {1, 2}, 'thing', {"fridge", "Bowmore_12yr"}, ...
     'price', {750, 1100});
```

- Typical application: data export, complex internal variables, data in GUI, ...

Function for Works with Structures I.

- New field creation:
  - Direct command.

```
stock(1).newField = 'test';
```

  - Field name as a string.

```
setfield(stock(1), 'newField', 'test')
```

```
stock(1).('newField2') = 'test2'
```

```
stock(2).("newField3") = 'test3'
```

- Setting field value:
  - Direct command.

```
stock(1).id = 3;
```

  - Field name and value.

```
stock(1).('id') = 3;
```

Function for Works with Structures II.

- List of all fields of structure – `fieldnames`.

```
fieldnames(stock)
```

- Value of given field.

```
id2 = stock(2).id
id2 = stock(2).('id')
id2 = getfield(stock(2), 'id')
```

- Does given field exist?

```
isfield(stock, 'id')  % = 1
isfield(stock, 'ID')  % = 0
```

- Is given variable a structure?

```
isstruct(stock)     % = 1
```

Function for Works with Structures III.

- Delete field.

```
rmfield(stock, 'id')
```

- More complex indexing of structures.
  - Structure may have more levels.

```
stock(1).subsection(1).order = 1
stock(1).subsection(2).order = 2
```

  - It is possible to combine cells with structures.

```
stock(1).subsection(3).check = [1; 2]
K{1} = stock;
```

  - Certain fields can be indexed using name stored as a string.

```
K{1}(1).subsection(3).('check')(2)
```

Function for Works with Structures IV.

- Getting data from fields of structure array.
  - Comma-separated list (doc Comma-Separated Lists).

```
stock.id
```

  - Concatenate values to vector.

```
allIDs = [stock.id] % row vector
allIDs = horzcat(stock.id) % row vector
allIDs = vertcat(stock.id) % column vector
```

  - Concatenate strings to cell array.

```
allThings = [stock.thing] % useless
allThings = vertcat(stock.thing) % error
allThings = {stock.thing} % cell array
```

  - Create multiple variables.

```
allThings = {stock.thing} % cell array
[th1, th2] = allThings{:}
```

Function for Works with Structures V.

- Set data to fields of structure array.
  - for cycle.

```
IDs = [2, 3];
for iStruct = 1:length(stock)
  stock(iStruct).id = IDs(iStruct);
end
```

  - Utilizing comma-separated list.

```
IDs = {2, 3};
[stock.id] = IDs{:};
```

- Creating multidimensional structure.

```
stock(2, 2).thing = 'multi dim.'
```

```
allThings = reshape({stock.thing}, size(stock)).'
```

Exercises

Exercise I.

- Find out how many spaces there are in the phrase “How are you?”.
  - Take a look in this lecture or MATLAB documentation and find out a suitable function.
  - Utilize logical indexing.
- Convert following string to lowercase and find number of charecters.

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

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Exercise II.a

- Create function that calculates volume, surface area or space diagonal of a cuboid.
  - The function accepts 4 input parameters: `a`, `b`, `c` and `attribute`, which take values `'volume'`, `'area'` or `'diagonal'`.
  - Calculate and return only an attribute required by the user.
  - Do not forget to check the input parameters.

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Exercise II.b

Exercise III.a

- Create so called tokenizer (text analyzer), that
  - reads a text input `str` entered by user using function `input`,
  - reads separator `sep` (space requires some care),
  - split `str` into 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.

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Exercise III.b

- Solution using `strtok`.

```
str = input('Enter a text: ', 's');
sep = input('Enter separator: ', 's');
if isempty(sep)    % treats all cases when sep = '' / ' '
   sep = ' ';
   fprintf('space ('' '') is used instead of nothing');
end

words   = cell(1, 1); % allocation
nVowels = zeros(1, 1); % allocation
here    = 1;
while ~isempty(str)
   [token, str]   = strtok(str, sep);
   words{here}    = token;
   nVowels(here)  = length(regexp(token, '[aeiyou]'));
   here           = here + 1;
end
celldisp(words);
fprintf('%s\n', mat2str(nVowels));
```

Exercise III.c

- Solution using `strsplit`.

```
clear; clc;
str = input('Enter a text: ', 's');
sep = input('Enter separator: ', 's');
if isempty(str)
   fprintf('''string'' is empty\n');
   return;
end
if isempty(sep)
   sep = ' ';
   fprintf('space ('' '') is used instead of nothing\n');
end

words  = strsplit(str, sep);
VS    = regexp(words, '[aeiyou]');
nVowels = cellfun(@length, VS);

celldisp(words);
fprintf('%s\n', mat2str(nVowels));
```

Exercise IV.a

- Try to create simple unit converter, length x 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';
switch units
  case 'mm' % conversion from mm to mm (no change)
     y = x;
  case 'cm' % conversion from cm to mm
     y = 1e1*x;
  case {'in', 'inch'} % inches to mm
     y = 2.54*x;
  otherwise
     fprintf('bad units');
     return;
end
fprintf('%0.5f%s is %0.5fmm\n', x, units, y);
```

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Exercise IV.b

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

```
function result = convertLength(in_val, in_unit, out_unit)
% supported units for conversion
conversion.in   = 1e4/254; % en.wikipedia.org/wiki/Imperial_units
conversion.inch = conversion.in;
conversion.mm   = 1e3;
conversion.cm   = 1e2;
conversion.m    = 1;

% are the units supported?
if ~isfield(conversion, in_unit)
   error('convertor:nonExistentUnit', ['Unknown unit: ' in_unit]);
end

% calculation
result = in_val * conversion.(out_unit) / conversion.(in_unit);
```

Questions?

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