

# Lecture 3: Functions

Math 98, Fall 2024

# Agenda

- Functions
- Exercises
- Anonymous Functions
- Functions vs. Scripts
- Local Functions
- `margin/return`
- Nested Functions

# Functions: Motivation

We have functions in addition to scripts because functions are

- ① reusable
  - ▶ A function replaces a repeated block of code.
- ② simplifying
  - ▶ A function organizes groups of code, and can be written in a separate file. Makes the code easier to read.
- ③ changeable
  - ▶ Easier to change a procedure if it's packaged by a single function.
- ④ modular
  - ▶ Reduce presence of intermediate variables

# Functions: Structure

Any function we write should have the following format:

```
%%%Name.m%%%\nfunction [output vars] = Name(input)\n\n    % code here\n\nend
```

The name of the function should match the name of the M-file. Built-in Matlab functions use all lowercase letters, so use at least one uppercase letter to avoid conflict.

# Functions: Example

Sample function:

```
function [n] = myfun(m)
    n = m + 1;
end
```

Using the function:

```
>> myfun(5)
ans =
    6
>> n = myfun(9)
n =
    10
>> blah = myfun(pi)
blah =
    4.1416
```

# Functions: Forgetting to assign output

Sample function:

```
function [n] = myfun(m)
    m + 1;
end
```

Using the function:

```
>> myfun(10)
>>
```

Nothing happens!! No output was assigned.

# Functions: Intermediate Variables

Sample function:

```
function [n] = myfun(m)
    a = m + 1;
    b = 2*a;
    n = b - 2;
end
```

Using the function:

```
>> n = myfun(4)
n =
    8
```

The 'outside world' knows nothing about the a and b that were created.  
What happens in the function stays in the function.....

## Exercise: myfun.m

Write a function of the form

```
function [sum, diff, prod] = myfun(a, b)
```

that takes in two numbers  $a$ ,  $b$  and returns their sum, difference, and product. Run each of the following lines and understand the result.

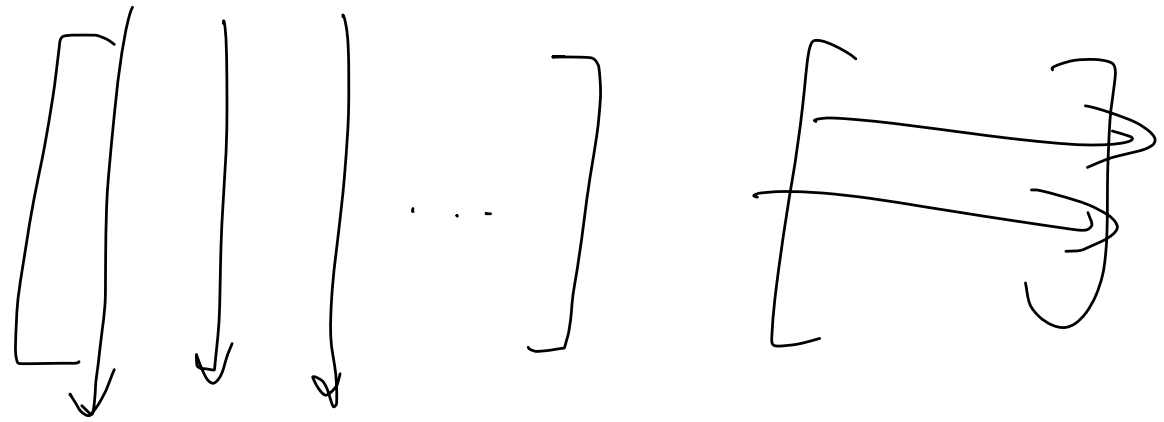
```
>> myfun(3, 4)
>> sum = myfun(3, 4)
>> prod = myfun(3, 4)
>> sum = myfun(3)
>> price = 5; units = 4; [~, ~, rev] = myfun(price, units)
```



# Exercise: sumrowcols.m

colsum

rowsum



Write a function of the form

```
function [colsum, rowsum] = sumrowcols(A)
```

that takes in a matrix  $m \times n$  matrix  $A$  and returns vectors `colsum` and `rowsum` of the column sums and row sums of  $A$ , respectively.

## Exercise: checkerboard.m

Write a function of the form

```
function A = checkerboard(n, m)
```

that takes two positive integers  $n$  and  $m$  as inputs and returns a matrix  $A$  such that every element of the  $n \times m$  output matrix for which the sum of its indices is even is 1. All other entries are zero.

Here is a sample output.

```
>> checkerboard(4, 5)
ans =
    1  0  1  0  1
    0  1  0  1  0
    1  0  1  0  1
    0  1  0  1  0
```

vector

$$v = [1 \ 0 \ 1 \ 0 \ \dots \ ]^m$$



$$\text{mod}(1:m, 2)$$

1	2	3	...	m
↓	↓	↓	...	
1	0	1	...	



$$v = \text{zeros}(1, m)$$

$$v(1:2:\text{end}) = 1$$

$$v([1, 3, 5, 7, \dots])$$

0	0	0	0	0	0	
↓		↓		↓		
1	0	1	0	1	0	...

matrix

$$M = \text{zeros}(n, m)$$

odd rows  
↓

odd cols  
↓

$$M(1:2:\text{end}, 1:2:\text{end}) = 1$$

1	0	1	0	...
0	0	0	0	...
1	0	1	0	...
0	0	0	0	...
⋮				

$$\rightarrow n \begin{bmatrix} 0 & 0 & 0 & \dots \\ 0 & 0 & 0 & \dots \\ 0 & & & \dots \end{bmatrix}^m$$

odd rows

want  $\begin{bmatrix} 1 & 0 & 1 & 0 & 1 & \dots \\ 1 & 0 & 1 & 0 & 1 & \dots \end{bmatrix}$

even rows

want  $\begin{bmatrix} 0 & 1 & 0 & 1 & \dots \\ 0 & 1 & 0 & 1 & \dots \end{bmatrix}$

$$M(2:2:\text{end}, 2:2:\text{end}) = 1$$

↓

1	0	1	0	...
0	1	0	1	...
⋮				

# Function Handles

A function handle is a Matlab variable that allows us to reference functions indirectly. Use them to include functions as inputs to or outputs from other functions.

```
>> integral(cos,0,1)
Error using cos
Not enough input arguments.
>> integral(@cos,0,1)
ans =
    0.8415
```

# Anonymous Functions

A way to define functions in the middle of a Matlab script or in the command line. Takes the form `functionName = @(inputs)(output)`, and returns the function handle `functionName`.

```
>> f = @(x,y)(x^2-y);  
>> f(10, 3)  
ans =  
    97  
>> fzero(@(x)(x^2-2), 1.5)  
ans =  
    1.4142
```

Useful when defining functions with simple expressions.

# Anonymous Functions: Examples

Here are some more functions:

```
>> b = 3; c = 5;
>> f1 = @(x)(x^3 + b*x + c);
>> fzero(f1,0)
ans =
    -1.1542
>> b = 2; c = -1;
>> f2 = @(x)(x^3 + b*x + c);
>> fzero(f2, 0)
ans =
    0.4534
```

Question: does changing the values of **b** and **c** change the function **f1**, or will **f1** and **f2** be different functions?

# Functions vs. Scripts

## Scripts:

- No inputs or outputs - Matlab just executes all commands
  - ▶ (Unless you use `input`)
- Operates on existing data in the workspace
- Variables created remain in the workspace

## Functions:

- Accept inputs and return outputs
- Create their own separate workspace
- Only requested output variables get saved

# Functions vs. Scripts: Accessing Variables in Workspace

Functions do not access variables stored in the main Workspace.

```
%%%exampleFunction.m%%%
```

```
function w = exampleFunction(x,y)  
    w = x + y + z;  
end
```

```
>> z = 5; a = exampleFunction(2,3);  
Undefined function or variable 'z'.
```



# Functions vs. Scripts: Saving Variables in Workspace

Functions do not save variables back to the main Workspace unless they are requested as outputs.

```
%%%exampleFunction.m%%%
```

```
function a = exampleFunction(x,y)  
    a = x + y; b = 101;  
end
```

```
>> a = exampleFunction(2,3); disp(a);  
    5  
>> disp(b)  
Undefined function or variable 'b'.
```

# Functions vs. Scripts: Conflicting Variables

Because functions use their own workspace, variables named inside a function cannot conflict with variables of the same name outside the function.

```
%%%exampleFunction.m%%%\n\nfunction a = exampleFunction(x,y)\n    b = 100; a = x + y + b;\nend
```

```
>> b = -300; a = exampleFunction(40,5); disp(a);\n    145\n>> disp(b);\n   -300
```

# Local Functions

We can define more than one function in a single file.

```
%%%myStats.m%%%
```

```
function avg = myStats(x)
```

```
% takes a vector and returns the average
```

```
    n = length(x);
```

```
    avg = myMean(x,n);
```

```
end
```

```
function m = myMean(v,n)
```

```
% it takes a vector and its length, returns the mean
```

```
    m = sum(v)/n;
```

```
end
```

Only the first function (the **main** function) can be called from other programs or the command line.

# Local Functions: In Scripts

We can also define local functions in scripts:

```
v = 1.5;  
L = myLength(v);  
fprintf('the length of v is %f \n', L);  
  
function len = myLength(x)  
    len = sqrt(sum(x.^2));  
end
```

Any function definitions must come at the end of the script.

# Commenting

As with built-in Matlab functions, we can use comments and `help` to inform how each function is properly used.

```
>> help myStats  
    takes a vector and returns the average  
>> help myStats>myMean  
    it takes a vector and its length, returns the mean
```

Any function definitions must come at the end of the script.

## nargin/return

When used in the code for a function, `nargin` is the number of inputs specified by the user. Handy when setting default values for inputs.

```
%%%addMe.m%%%  
%Input: one or two floating point numbers  
%Output: addMe(x,y) returns x + y; addMe(x) returns 2*x  
function s = addMe(x,y)  
    if (nargin == 1)  
        s = x + x;  
    elseif (nargin == 2)  
        s = x + y;  
    else  
        fprintf('Read the comments! \n');  
        return  
    end  
end  
end
```

`return` automatically halts the function

## Exercise: myCosine.m

Write a function `myCosine(theta,units)` that returns the cosine of an angle. If the second parameter is 'deg', convert the angle to radians with a local function `DegToRadians(x)` before using Matlab's `cos`. In all other cases (including no second parameter), assume the angle is in radians.

```
>> myCosine(180, 'deg')
ans =
    -1
>> myCosine(pi, 'rad')
ans =
    -1
>> myCosine(pi)
ans =
    -1
```

# Problem

We would like to find the roots of the polynomial

$$p(x) = x^3 + bx + c$$

for various numbers  $b, c \in \mathbb{R}$ .

- How can we produce this family of functions?
- What tools does Matlab have to solve this problem?



# Nested Functions

Nested functions are functions defined within other functions.

```
function f = makeCubic(b,c)
    function y = myCubic(x)
        y = x.^3 + b*x + c;
    end

    f = @myCubic;
end
```

They can access variables in the workspace of the parent function, and don't need to be defined at the end of the code in the parent function.

Use `fzero`  
to find all of the zeros of  
 $x^3 - 5m(x)$