

Matlab and Programming 1

Programming basics and algorithms

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Today's outline

① Introduction

② Variables

③ Creating algorithms

④ Functions

⑤ Conclusions

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Programming

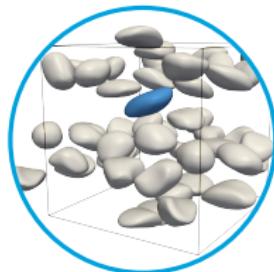
“Everybody in this country should learn to program a computer, because it teaches you to think..”

—Steve Jobs



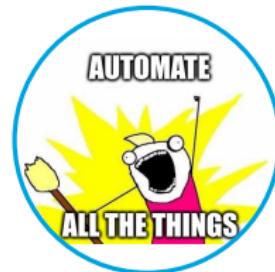
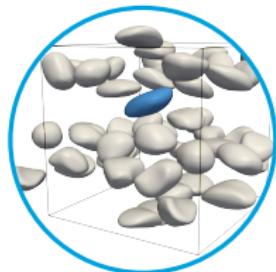
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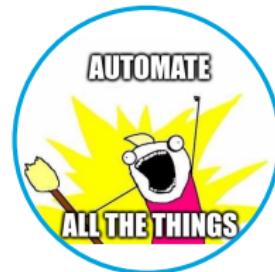
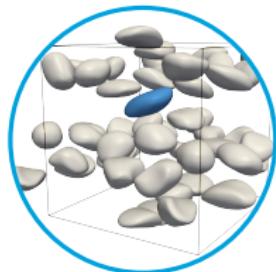
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- Knowledge of programming allows you to automate routine tasks



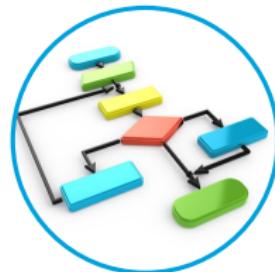
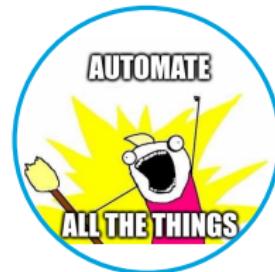
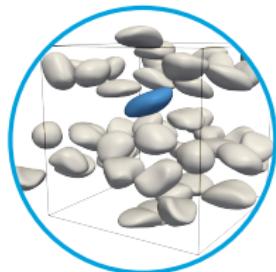
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- Ability to understand algorithms by inspection of the code



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- Scientific techniques depend in an increasing fashion upon computer programs and simulation methods
- Knowledge of programming allows you to automate routine tasks
- Ability to understand algorithms by inspection of the code
- Learn to think by dissecting a problem into smaller bits



Getting started

Start Matlab, and enter the following commands on the command line. Evaluate the output.

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>> 8/a-b
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>> 8/a-b
>> sin(a)          % Mathematical functions can be used
>> sin(0.5*pi)    % pi is an internal Matlab variable
>> 1/0              % Infinity is a thing ...
>> sqrt(-1)        % ... as are imaginary numbers
```

Introduction to programming

What is a program?

A program is a sequence of instructions that is written to perform a certain task on a computer.

- The computation might be something mathematical, such as solving a system of equations or finding the roots of a polynomial
- It can also be a symbolic computation, such as searching and replacing text in a document
- A program may even be used to compile another program
- A program consists of one or more *algorithms*

Getting started

- Use an *integrated development environment*
 - Matlab
 - MS Visual Studio/Code
 - Eclipse
 - Dev C++
 - IDLE, Canopy (express)
- Create a simple program:
 - Hello world
 - Find the roots of a parabola
 - Find the greatest common divisor of two numbers

Some often used programming languages

Python

- Many functionalities available
- Smooth learning curve
- Slow compared to compiled languages
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- Low learning curve
- Very limited for larger problems, unbeatable for quick calculations
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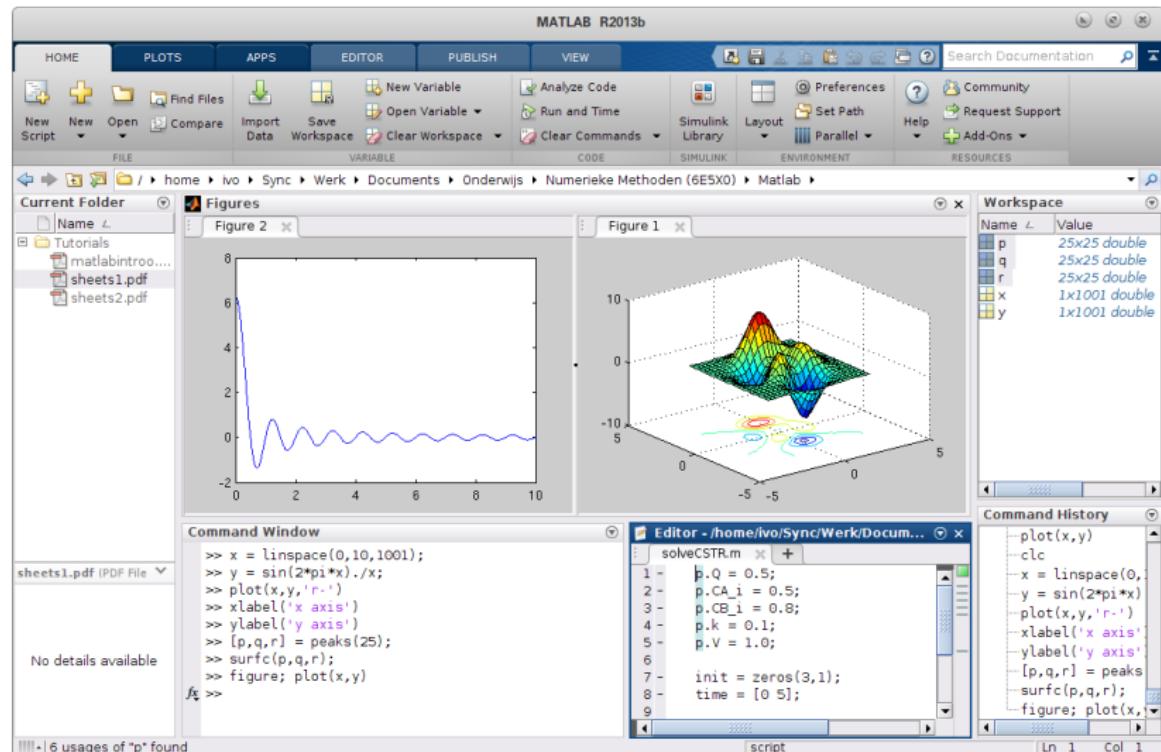
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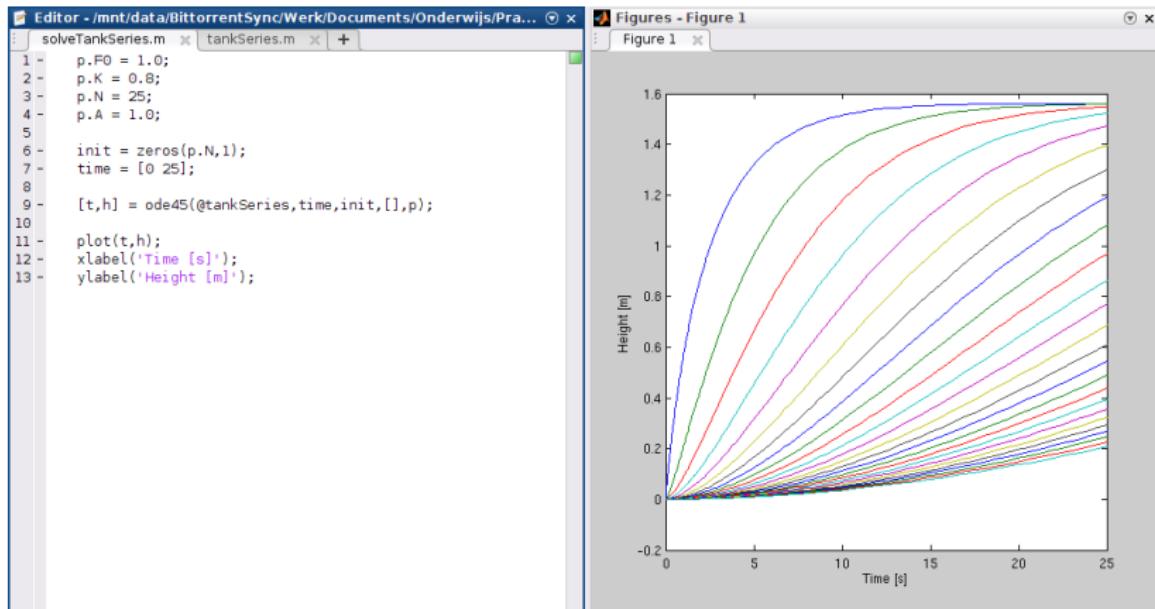
- Many functionalities built-in (80+ toolkits!)
- Slow compared to compiled languages

- Fairly smooth learning curve
- Needs a license (alternatives: SciLab, GNU Octave)

Versatility of Matlab



Versatility of Matlab: ODE solver



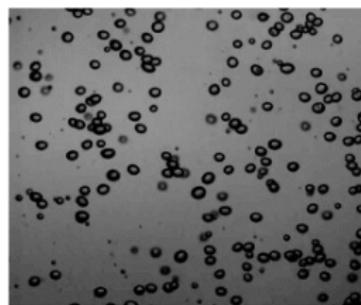
Versatility of Matlab: Image analysis

```
I = imread('bubbles.png');  
BW = rgb2gray(I);  
E = edge(BW, 'canny');  
F = imfill(E, 'holes');  
result = regionprops(F);
```



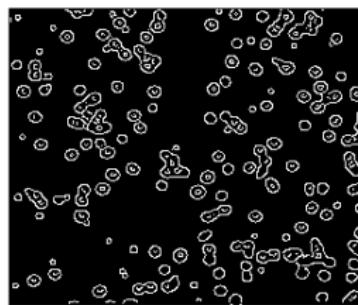
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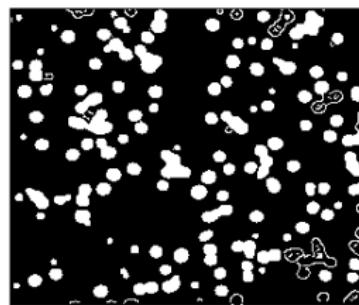
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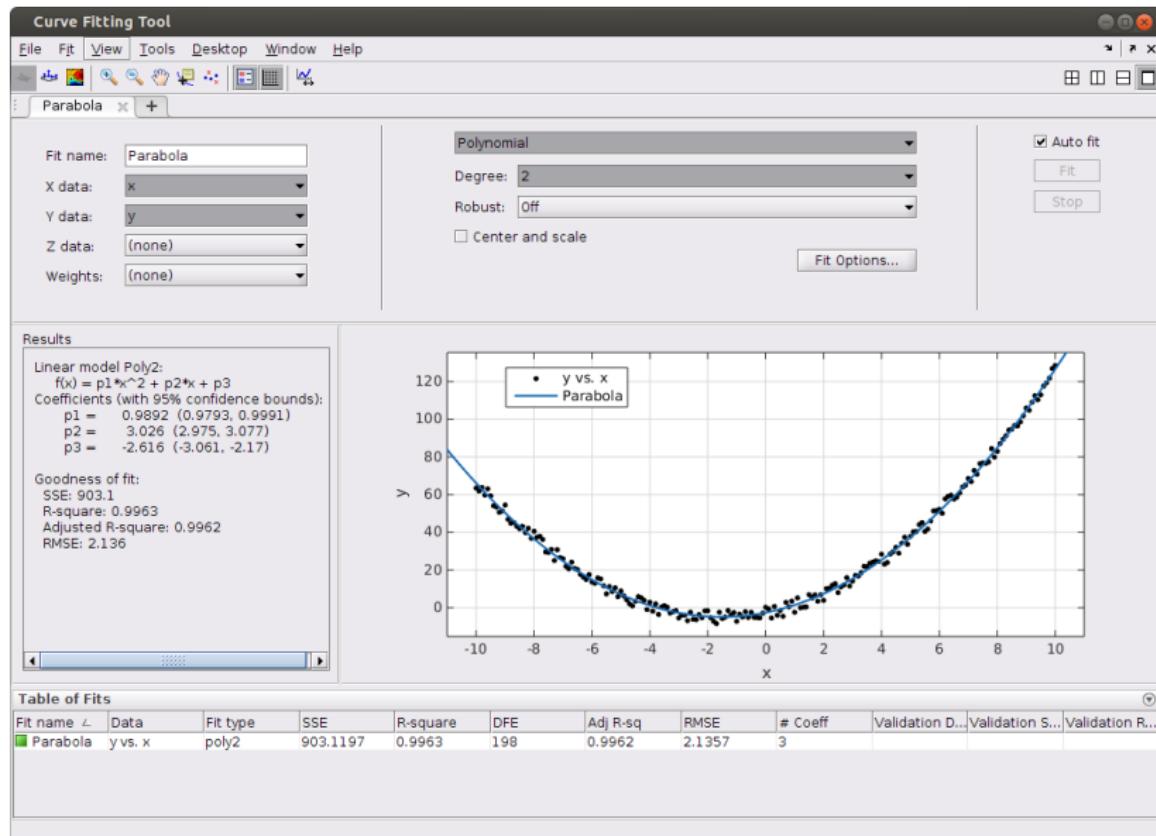


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Versatility of Matlab: Curve fitting



Matlab help

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- Search the web!



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Terminology

Variable Piece of data stored in the computer memory, to be referenced and/or manipulated

Function Piece of code that performs a certain operation/sequence of operations on given input

Operators Mathematical operators (e.g. + - * or /), relational (e.g. < >or ==, and logical operators (&&, ||)

Script Piece of code that performs a certain sequence of operations without specified input/output

Expression A command that combines variables, functions, operators and/or values to produce a result.

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- If you don't assign a variable, it will be stored in `ans`
- Clearing the workspace is done with `clear`.

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A row vector:

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>> v = [0 1 2 3]
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Transposing vectors:

```
>> w = v'
```

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Manual definition may be cumbersome. A colon (:) generates a list:

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>> a = 1:10      % Default stride is 1  
>> x = -1:.1:1   % start:stride:stop specifies list
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>> y = linspace(0,10,11)  
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Or (by supplying a vector instead of a scalar):

```
>> y([1 4:7]) = 16:20 % equivalent to y([1 4 5 6 7]) =  
[16 17 18 19 20]
```

Practice

Given a vector

$$x = [2 \ 4 \ 6 \ 8 \ 10 \ 12 \ 14 \ 16 \ 18 \ 20 \ 30 \ 40 \ 50 \ 60 \ 70 \ 80]$$

- Find a way to define the vector without typing all individual elements

Practice

Given a vector

$$x = [2 \ 4 \ 6 \ 8 \ 10 \ 12 \ 14 \ 16 \ 18 \ 20 \ 30 \ 40 \ 50 \ 60 \ 70 \ 80]$$

- Find a way to define the vector without typing all individual elements
- Investigate the meaning of the following commands:

```
>> y = x(5:end)  
>> y(4)  
>> y(4) = []  
>> sum(x)  
>> mean(x)  
>> std(x)  
>> max(x)  
>> fliplr(x)  
>> diff(x)
```

Operations on vectors (1)

```
>> e = 1:5  
>> f = 2*e  
>> g = 4*f + 20
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Matlab uses matrix operations by default, we should use a dot operator to make operations element-wise for *, / and ^.

```
>> e.^2
```

Operations on vectors (2)

To demonstrate the matrix product:

```
>> p = [1; 1; 1]
>> q = [1 2 3]
>> p*q    % which is not equal to q*p
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All kinds of mathematical functions on vectors typically operate on elements:

```
>> x = linspace(0,2*pi,100);
>> s = sin(x)
>> e = exp(x)
```

Building blocks: Mathematics and number manipulation

Programming languages usually support the use of various mathematical functions (sometimes via a specialized library). Some examples of the most elementary functions in Matlab:

Command	Explanation
<code>cos(x)</code> , <code>sin(x)</code> , <code>tan(x)</code>	Cosine, sine or tangens of x
<code>mean(x)</code> , <code>std(x)</code>	Mean, st. deviation of vector x
<code>exp(x)</code>	Value of the exponential function e^x
<code>log10(x)</code> , <code>log(x)</code>	Base-10/Natural logarithm of x
<code>floor(x)</code>	Largest integer smaller than x
<code>ceil(x)</code>	Smallest integer that exceeds x
<code>abs(x)</code>	Absolute value of x
<code>size(x)</code>	Size of a vector x
<code>length(x)</code>	Number of elements in a vector x
<code>rem(x,y)</code>	Remainder of division of x by y

Printing results

You can prevent displaying the outcome of a command by adding a semi-colon at the end of a line:

```
>> c = linspace(0,10,11);  
>> length(c)  
>> c  
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Altering the display format can be done using the `format` command:

```
>> format compact % loose  
>> format long % short
```

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Make a plot of the following table

T (°C)	5	20	30	50	55
μ (Pa·s)	0.08	0.015	0.009	0.006	0.0055

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```
>> plot(x,y)
```

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>> xlabel('Temperature ^\circC')  
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>> title('Experiment 1')
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>> plot(x,y, '*')
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>> plot(x,y, 'r--')
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>> plot(x,y, 'ko-', 'LineWidth', 2)
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Practice

Create plots of the following functions in a single figure for $x \in \{0, 2\pi\}$:

$$y_1 = \cos x$$

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Strategies to draw multiple graphs in 1 figure:

```
>> plot(x,y1,x,y2,x,y3)
```

```
>> plot(x,y1)
>> hold on; % Maintain drawn plots in current figure
>> plot(x,y2)
>> plot(x,y3) % The 'hold-property' was already set
```

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$$A = \begin{bmatrix} 8 & 1 & 6 \\ 3 & 5 & 7 \\ 4 & 9 & 2 \end{bmatrix}$$

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>> A(3,1) % Third row, first column, also A(3)
>> A(3,:) = [2 4 8] % Set entire third row
>> A(:,3) % Print third column
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There are a few functions that help creating matrices:

```
>> A = zeros(4) % A 4x4 matrix with zeros
>> A = ones(4,1) % A 4-element vector with ones
>> A = eye(3) % Identity matrix of 3x3
>> A = rand(3,4) % A 3x4 matrix with random numbers
```

Practice

- Find a *short* Matlab expression to create the following matrix:

$$A = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 9 & 7 & 5 & 3 & 1 & -1 & -3 \\ 4 & 8 & 16 & 32 & 64 & 128 & 256 \end{bmatrix}$$

Practice

- Find a *short* Matlab expression to create the following matrix:

$$A = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 9 & 7 & 5 & 3 & 1 & -1 & -3 \\ 4 & 8 & 16 & 32 & 64 & 128 & 256 \end{bmatrix}$$

- Investigate the command `max(A)`. What does it give?
- How to obtain the maximum for each row?
- Use a vector multiplication to compute the following matrix:

$$A = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & 2 \\ 3 & 3 & 3 & 3 \\ 4 & 4 & 4 & 4 \end{bmatrix}$$

Datatypes and variables

Matlab uses different types of variables:

Datatype	Example
string	'Wednesday'
integer	15
float	0.15
vector	[0.0; 0.1; 0.2]
matrix	[0.0 0.1 0.2; 0.3 0.4 0.5]
struct	sct.name = 'MyDataName'
	sct.number = 13
logical	0 (false)
	1 (true)

About variables

- Matlab variables can change their type as the program proceeds (this is not common for other programming languages!):

```
>> s = 'This is a string'  
s =  
This is a string  
>> s = 10  
s =  
10
```

- Vectors and matrices are essentially *arrays* of another data type. A vector of *struct* is therefore possible.
- Variables are *local* to a function (more on this later).

Today's outline

① Introduction

② Variables

③ Creating algorithms

④ Functions

⑤ Conclusions

Building blocks: conditional statements

if-statement: Check whether a (set of) condition(s) is met.

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```
num = floor (10 * rand + 1);
guess = input ('Your guess please : ');
if ( guess ~= num )
    disp (['Wrong, it was ',num2str(num),'. Kbye.']);
else
    disp ('Correct !');
end
```

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```

Other relational operators

==	is equal to
<=	is less than or equal to
>=	is greater than or equal to
<	is less than
>	is greater than

Combining conditional statements

&&	and
 	or
xor	exclusive or

Building blocks: loops

for-loop: Performs a block of code a certain number of times.

Building blocks: loops

for-loop: Performs a block of code a certain number of times.

```
>> p(1) = 1;
>> p(2) = 1;
>> for i = 2:10
p(i+1) = p(i)+p(i-1);
end
>> p
p =
    1     1     2     3     5     8    13    21    34    55    89
```

Building blocks: indeterminate repetition

while-loop: Performs and repeats a block of code until a certain condition.

Building blocks: indeterminate repetition

`while`-loop: Performs and repeats a block of code until a certain condition.

```
num = floor (10* rand +1) ;
guess = input ('Your guess please : ');

while ( guess ~= num )
    guess = input ('That is wrong. Try again ... ');
end

if (isempty(guess))
    disp('No number supplied - exit');
else
    disp ('Correct!');
end
```

Example algorithm

Compute the factorial of N : $N! = N \cdot (N - 1) \cdot (N - 2) \cdots 2 \cdot 1$

How to deal with this?

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For-loop

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    Z = Z*i;  
end
```

While-loop

```
Z = 1;  
i = 1;  
while (i<=N)  
    Z = Z*i;  
    i = i+1;  
end
```

Note: N must be set beforehand!

Note: Pay attention to the relational operators!

Building blocks: case selection

`switch`-statement: Selects and runs a block of code.

Building blocks: case selection

switch-statement: Selects and runs a block of code.

```
[dnum,dnam] = weekday(now);
switch dnum
    case {1,7}
        disp('Yay! It is weekend!');
    case 6
        disp('Hooray! It is Friday!');
    case {2,3,4,5}
        disp(['Today is ', dnam]);
    otherwise
        disp('Today is not a good day...');

end
```

Input and output

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```

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- Input may be read from a file, e.g.

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>> data = getfield(importdata('myData.txt', ' ', 4), 'data');  
>> numdata = xlsread('myExcelDataFile.xls');
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- There are many more advanced functions, e.g. `fread`, `fgets`, ...

Input and output

Output of results to screen, storing arrays to a file or exporting a graphic are the most common ways of getting data out of Matlab:

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- Save variables automatically (scripted):

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>> p = rand(1,10);
>> q = ones(10);
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- More advanced functions can be found in e.g. `fwrite`, `fprintf`,
...

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Functions - general

A function in a programming language is a program fragment that performs a certain task. Creating functions keeps your code clean, re-usable and structured.

- You can use functions supplied by the programming language, and define functions yourself
- Functions take one or more input parameters (*arguments*), and *return* an output (*result*).
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```
function [out1, out2] = myFunction(in1, in2, in3)
```

Functions - locality and arguments

- You are supplying arguments to a function because it does not have access to previously defined variables. This is called *locality*.
 - This does not include global variables - but they're evil!
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Exercise: write a function that takes 3 variables, and returns the average:

Approach 1

```
function res = avg1(a,b,c)
    mySum = a + b + c;
    res = mySum / 3;
end
```

Approach 2

```
function res = avg2(a,b,c)
    data = [a; b; c];
    res = mean(data);
end
```

Exercise: create a function

Compute $N! = N \cdot (N - 1) \cdot (N - 2) \cdots 2 \cdot 1$

Create a function of our while-loop approach with N the argument:

Original script

```
Z = 1;  
i = 1;  
while (i<=N)  
    Z = Z*i;  
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end
```

Function

```
function Z = fact_while(N)  
  
Z = 1;  
i = 1;  
while (i<=N)  
    Z = Z*i;  
    i = i+1;  
end  
  
end
```

Functions - checking input

The function we created computes the factorial correctly!

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- In this case, we should check the user input to prevent an infinite loop:

```
if (fix(N) ~= N) | (N < 0)
    disp 'Provide a positive
          integer number!'
    return;
end
```

- If no check can be done before a while-loop, you may want to stop after x loops

Functions - checking input

The whole factorial function, including comments:

```
function Z = fact_while(N)
    % This function computes a factorial of input value N
    % Usage   : fact_while(N)
    % N       : value of which the factorial is computed
    % returns: factorial of N

    % Catch non-integer case
    if (fix(N) ~= N) | (N < 0)
        disp 'Provide a positive integer number!'
        return;
    end

    Z = 1;
    i = 1;
    while (i <= N)
        Z = Z*i;
        i = i+1;
    end
```

Recursion

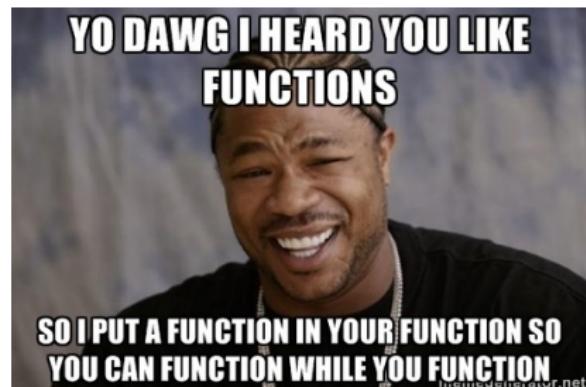
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- In order to understand recursion, one must first understand recursion
- A recursive function is called by itself (a function within a function)
 - This could lead to infinite calls;
 - A base case is required so that recursion is stopped;
 - Base case does not call itself, simply returns.



Recursion: example

```
function out = mystery(a,b)
if (b == 1)
    % Base case
    out = a;
else
    % Recursive function call
    out = a + mystery(a,b-1);
end
```

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- What does this function do?
- Can you spot the error?

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- What does this function do?
- Can you spot the error?
- How deep can you go? Which values of b don't work anymore?

Recursion: exercise

Create a function computing the factorial of N , based on recursion.

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Create a function computing the factorial of N , based on recursion.

```
function res = fact_recursive(x)

% Catch non-integer case
if (fix(x) ~= x) | (x<0)
    disp 'You should provide a positive integer number
          only'
    return;
end

if (x > 1)
    res = x*fact_recursive(x-1);
else
    res = 1;
end

end
```

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In conclusion...

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