

Unit 5: Subprograms

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Objectives

- Understand the need of organizing the code in scripts and functions
- Learn to write functions and scripts in MATLAB
- Understand how parameters are passed to a function
- Know the different types of variables

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Programme modules

- Programs may be too long and complex to write as a single unit.
- A program can be logically divided in smaller subprograms or modules
- Advantages:
 - Divide and Rule
 - Easier to maintain and to debug
 - Easier to reuse

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Modular Programming in MATLAB

- There are two kinds of M-files (*.m):
 - Scripts:
 - They operate on data in the main workspace.
 - Do not accept input arguments or return output arguments.
 - Functions:
 - Internal variables are local to the function
 - They can accept input arguments and return output arguments.

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Scripts or m-files

- Contain sequences of MATLAB commands
- Whenever a command produces an output the result is visualized in the Command Window
- They can be executed from...

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Scripts or m-files

- Contain sequences of MATLAB commands
- They can be executed from...
 - Command window: typing the name of the script
 - MATLAB editor: using the 'run' icon
 - Other script: including the name of the script in the sequence of commands (*calls*)

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Scripts or m-files: calls

Script1

```
_____  
_____  
_____  
_____  
_____  
  
name_of_script2  
  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____
```

Script2

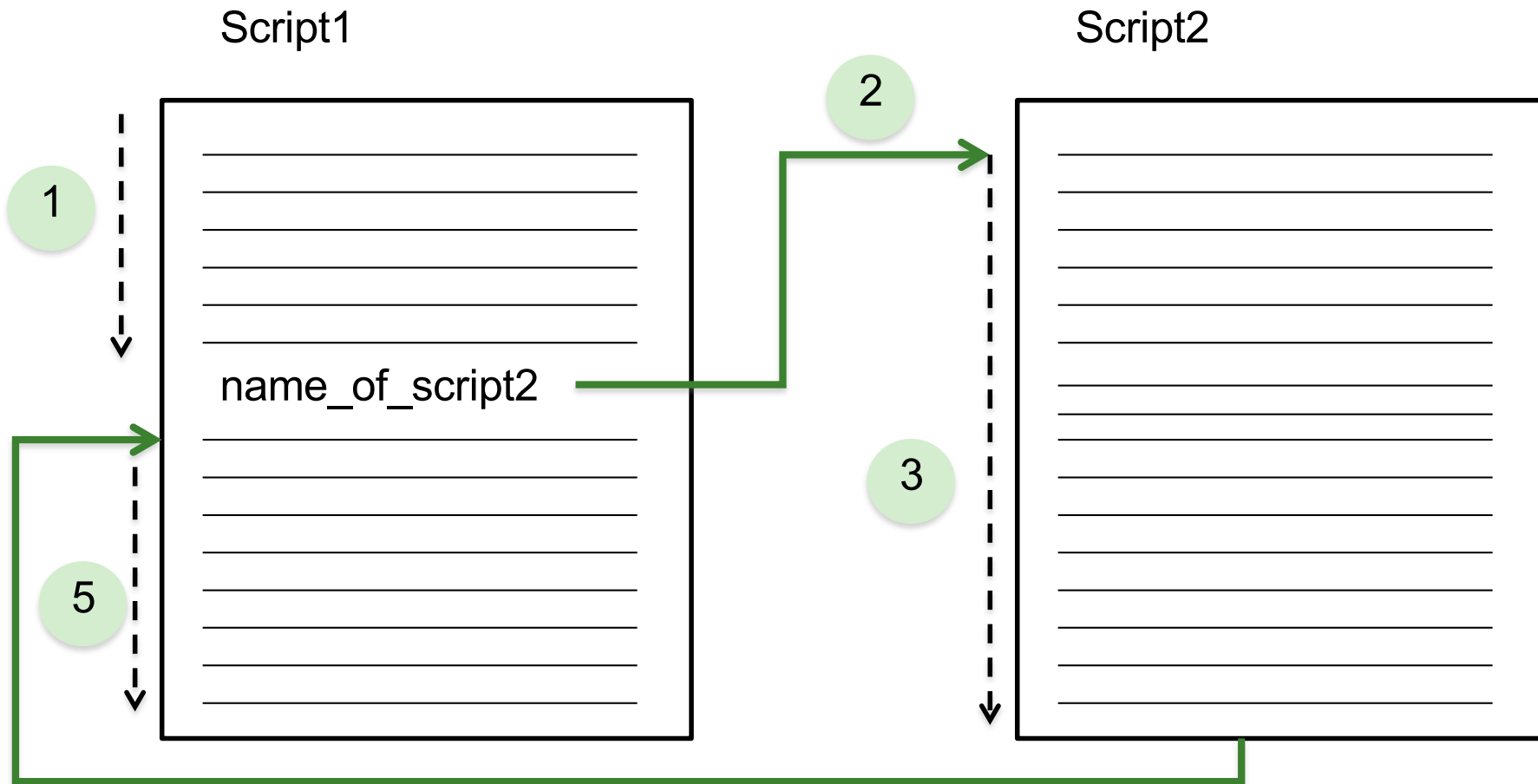
```
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____  
_____
```

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Scripts or m-files: calls



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Scripts or m-files: variables

- Scripts can operate on existing variables of the workspace, or they can create new variables on which to operate.
- When a script is executed from the command window or called from another script the variables created belong to the MATLAB workspace

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Scripts or m-files. Example of CALL

```
% Script example 1
driver = 'f';
years = 27;
scriptExample2;
fprintf('the dto is %d', dto);
```

```
% Script example 2
if (driver == 'f') &(years < 30)
    dto = 10;
else
    dto = 5;
end;
```

MATLAB WORKSPACE



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Scripts or m-files. Example of CALL

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% Script example 1  
driver = 'f';  
years = 27;  
▼ scriptExample2;  
fprintf('the dto is %d', dto);
```

```
% Script example 2  
if (driver == 'f') &(years < 30)  
    dto = 10;  
else  
    dto = 5;  
end;
```

MATLAB WORKSPACE

Variable name	→	driver	years
Variable value	→	f	27

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Scripts or m-files. Example of CALL

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% Script example 1  
driver = 'f';  
years = 27;  
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% Script example 2  
if (driver == 'f') &(years < 30)  
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    dto = 5;  
end;
```

MATLAB WORKSPACE

Variable name	→	driver	years
Variable value	→	f	27

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Scripts or m-files. Example of CALL

```
% Script example 1  
driver = 'f';  
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if (driver == 'f') &(years < 30)  
    dto = 10;  
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    dto = 5;  
end;
```

MATLAB WORKSPACE

Variable name	→	driver	years	dto
Variable value	→	f	27	10

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Scripts or m-files. Example of CALL

```
% Script example 1  
driver = 'f';  
years = 27;  
scriptExample2;  
fprintf('the dto is %d', dto);
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```
% Script example 2  
if (driver == 'f') &(years < 30)  
    dto = 10;  
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    dto = 5;  
end;
```

MATLAB WORKSPACE

Variable name	→	driver	years	dto
Variable value	→	f	27	10

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Scripts or m-files. Example of CALL

```
% Script example 1
driver = 'f';
years = 27;
scriptExample2;
↓
fprintf('the dto is %d', dto);
```

```
% Script example 2
if (driver == 'f') &(years < 30)
    dto = 10;
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    dto = 5;
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```

MATLAB WORKSPACE

Variable name	→	driver	years	dto
Variable value	→	f	27	10

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Scripts or m-files: variables

■ Useful commands:

- `echo on/off`: when activated (`echo on`) prints the commands in the script as they are executed.
 - This can be very useful when debugging (finding errors) in our programs
- `help scriptname`: shows the first two lines of comments of the script. Useful for documenting.
- `clear`: cleans the workspace, removing all the existing variables.

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Functions

- MATLAB allows users to create their own functions, which will work in a similar way to the MATLAB functions *rem*, *floor*, *sqrt*..
- User functions are defined in m-files in a similar way to the scripts but following a specific syntax
- User functions can be called from the command window, from scripts or from other functions
 - Each call must supply values for the input arguments of the function and retrieve the values of the output arguments

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Functions. Example

The code is stored
in a file named
obtainSalary.m

```
function [salary]= obtainSalary(wage, hoursWorked)
```

```
% Function to compute the salary of a worker
```

```
% Extra hours are paid a 50% more
```

```
% wage = wage of the worker in euros
```

```
% hoursWorked = hours worker per week
```

```
% extra = extra salary of the worker per week
```

```
% salary = salary of the worker per week
```

```
base = wage * hoursWorked;
```

```
if (hoursWorked > 40)
```

```
    extra = (hoursWorked-40) * wage /2;
```

```
else
```

```
    extra = 0;
```

```
end
```

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Function definition

```
function [salary]= obtainSalary(wage, hoursWorked)
```

Function definition

```
% Function to compute the salary of a worker
```

H1 line

```
% Extra hours are paid a 50% more
```

```
% wage = wage of the worker in euros
```

```
% hoursWorked = hours worker per week
```

```
% extra = extra salary of the worker per week
```

```
% salary = salary of the worker per week
```

Help text

```
base = wage * hoursWorked;
```

```
if (hoursWorked > 40)
```

```
    extra = (hoursWorked-40) * wage /2;
```

```
else
```

```
    extra = 0;
```

```
end
```

Body of the function

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Function definition

```
function [salary]= obtainSalary(wage, hoursWorked)
```

**Function
definition**

```
% Function to compute the salary of a worker
```

H1 line

```
% Extra hours are paid a 50% more
```

```
% wage = wage of the worker in euros
```

```
% hoursWorked = hours worker per week
```

```
% extra = extra salary of the worker per week
```

```
% salary = salary of the worker per week
```

Help text

```
base = wage * hoursWorked;
```

```
if (hoursWorked > 40)
```

```
    extra = (hoursWorked-40) * wage /2;
```

```
else
```

```
    extra = 0;
```

```
end
```

**Body of
the function**

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Function definition

- Function definition
 - First line of the code
 - Indicates that the file contains a function
 - Defines the function name
 - Defines the number and order of the input and output parameters

```
function [output arguments]= function_name (input paramaters)
```



Function keyword.
Always in lowercase



List of output
arguments separated
by commas. A function



Name of the function.
Can be composed of
characters, digits and



List of input parameters
separated by commas. A
function may have from

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the code

Interactive Systems Group

Function definition

```
function [salary]= obtainSalary(wage, hoursWorked)
```

Function definition

```
% Function to compute the salary of a worker
```

H1 line

```
% Extra hours are paid a 50% more
```

```
% wage = wage of the worker in euros
```

```
% hoursWorked = hours worker per week
```

```
% extra = extra salary of the worker per week
```

```
% salary = salary of the worker per week
```

Help text

```
base = wage * hoursWorked;
```

```
if (hoursWorked > 40)
```

```
    extra = (hoursWorked-40) * wage /2;
```

```
else
```

```
    extra = 0;
```

```
end
```

Body of the function

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Function definition

- The H1 line and help lines are comments which makes it easy to document your functions
- H1 line:
 - First comment line of the function
 - Normally contains the name of the function and a brief description
 - When a user types `lookfor word` in the command window MATLAB retrieves all the H1 lines which contains that word
- Help lines:
 - Comment lines between the H1 line and the first line of code
 - The command `help function_name` retrieves the help lines

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Function definition

```
function [salary]= obtainSalary(wage, hoursWorked)
```

Function definition

```
% Function to compute the salary of a worker
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H1 line

```
% Extra hours are paid a 50% more
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% wage = wage of the worker in euros
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% hoursWorked = hours worker per week
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% extra = extra salary of the worker per week
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% salary = salary of the worker per week
```

Help text

```
base = wage * hoursWorked;
```

```
if (hoursWorked > 40)
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```
    extra = (hoursWorked-40) * wage /2;
```

```
else
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    extra = 0;
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```
end
```

Body of the function

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Do not put a : at the end of this line or you will get an error

Active Systems Group

Functions. Example of call

exercise1.m

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);
```

obtainSalary.m

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week  
  
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage /2;  
else
```

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Functions. Example of call

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);
```

The values of the variables *yourWage* and *yourHourse* are copied to the function's variables (arguments) *wage* and *hoursWorked*

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week  
  
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage / 2;  
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```

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Functions. Example of call

```
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yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);
```

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week  
  
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage / 2;  
else
```

When Matlab finishes executing the function the value of the variable *salary* is copied to the variable *yourSalary*.

(Matlab does this because the name of variable *salary* appears in

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Functions. Example with 2 output values

```
function [salary, extra]= obtainSalary(wage, hoursWorked)
```

```
% Function to compute the salary of a worker
```

```
% Extra hours are paid a 50% more
```

```
% wage = wage of the worker in euros
```

```
% hoursWorked = hours worker per week
```

```
% extra = extra salary of the worker per week
```

```
% salary = salary of the worker per week
```

```
base = wage * hoursWorked;
```

```
if (hoursWorked > 40)
```

```
    extra = (hoursWorked-40) * wage /2;
```

```
else
```

```
    extra = 0;
```

```
end.
```

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Functions. Example with 2 output values. Call

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
[yourSalary, yourExtra] = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);  
fprintf('Your extra is %d', yourExtra);
```

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Functions. Example with 2 output values. Call

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% salary = salary of the worker per week
```

```
base = wage * hoursWorked;
```

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```
end
```

end

Passing parameters to a function

- There are two different ways in which a **programming language** may implement the calls of functions:
 - **Pass by values:** The values of the variables of the calling code are copied into the variables specified as parameters of the functions.
 - **Changes in these variables do not modify the values of the variables of the calling code.**
 - **Pass by reference:** Changes in the variables of the function modify the values of the variables passed as parameters in the calling code.

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Local Variables

- Local variables:

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Local Variables

- Local variables:
 - **Every function has its own *function workspace*** separated from the workspace used by the command window and the scripts, and the workspaces of the rest of the functions.

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Local Variables

- Local variables:
 - **Every function has its own *function workspace*** separated from the workspace used by the command window and the scripts, and the workspaces of the rest of the functions.
 - **Variables defined in the body of a function** (including input and output arguments) **are only recognized inside the function scope.**

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Local Variables

- Local variables:
 - ❑ **Every function has its own *function workspace*** separated from the workspace used by the command window and the scripts, and the workspaces of the rest of the functions.
 - ❑ **Variables defined in the body of a function** (including input and output arguments) **are only recognized inside the function scope.**
 - ❑ Once the execution of the function finished **its workspace is eliminated and the current value**

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Local Variables

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);
```

salary, wage, hoursworked,
base and *extra* are **LOCAL VARIABLES**. They belong to the **function workspace**

yourwage, yourHours, and *yourSalary* are **NOT**

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week  
  
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage /2;
```

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Local Variables

STEP 1. The user introduces his/her wage and hours

```
yourWage = input('Introduce your wage'); ← 500
yourHours = input('Introduce the hours worked'); ← 20
yourSalary = obtainSalary(yourWage, yourHours);
fprintf('Your salary is %d', yourSalary);
```

MATLAB WORKSPACE

yourWage	yourHours
500	20

```
function [salary]= obtainSalary(wage, hoursWorked)
% Function to compute the salary of a worker
% Extra hours are paid a 50% more
% wage = wage of the worker in euros
% hoursWorked = hours worker per week
% extra = extra salary of the worker per week
% salary = salary of the worker per week

base = wage * hoursWorked;
if (hoursWorked > 40)
    extra = (hoursWorked-40) * wage /2;
```

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Local Variables

STEP 2. The function obtain salary is called

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);
```

MATLAB WORKSPACE

yourWage	yourHours
500	20

FUNCTION WORKSPACE

wage	hoursWorked
------	-------------

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week  
  
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage /2;
```

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Local Variables

STEP 3. The function obtain salary is executed

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);
```

MATLAB WORKSPACE

yourWage	yourHours
500	20

FUNCTION WORKSPACE

wage	hoursWorked	base	salary	extra
------	-------------	------	--------	-------

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week  
  
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage /2;
```

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Local Variables

STEP 4. The execution of the function finished and Matlab continue on and prints the salary on screen

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);
```

MATLAB WORKSPACE

yourWage	yourHours	yourSalary
500	20	1000

FUNCTION WORKSPACE

wage	DELETED	salary	extra
------	---------	--------	-------

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week  
  
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage /2;
```

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Local Variables

```
yourWage = input('Introduce your wage'); ← 500
yourHours = input('Introduce the hours worked'); ← 20
yourSalary = obtainSalary(yourWage, yourHours);
fprintf('Your salary is %d', yourSalary);
fprintf('Value of salary %d', salary);
```

If we add this last line...
what MATLAB will print
on screen?

```
function [salary]= obtainSalary(wage, hoursWorked)
% Function to compute the salary of a worker
% Extra hours are paid a 50% more
% wage = wage of the worker in euros
% hoursWorked = hours worker per week
% extra = extra salary of the worker per week
% salary = salary of the worker per week

base = wage * hoursWorked;
if (hoursWorked > 40)
    extra = (hoursWorked-40) * wage /2;
```

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Local Variables

```
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);  
fprintf('Value of salary %d', salary);
```

500

20

Matlab will give an **error** as the variable 'salary' does not exist in its workspace

```
function [salary]= obtainSalary(wage, hoursWorked)
```

```
function to compute the salary of a worker  
extra hours are paid a 50% more  
wage = wage of the worker in euros  
hoursWorked = hours worker per week
```

```
% extra = extra salary of the worker per week  
% salary = salary of the worker per week
```

```
base = wage * hoursWorked;  
if (hoursWorked > 40)  
    extra = (hoursWorked-40) * wage / 2;
```

MATLAB WORKSPACE

yourWage	yourHours	yourSalary
500	20	10000

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Local Variables

```
salary = 0;
```

```
yourWage = input('Introduce your wage');
```

```
yourHours = input('Introduce the hours worked');
```

```
yourSalary = obtainSalary(yourWage, yourHours);
```

```
fprintf('Your salary is %d', yourSalary);
```

```
fprintf('Value of salary %d', salary);
```

500

20

And if we add the first and last line... what MATLAB will print on screen?

```
function [salary]= obtainSalary(wage, hoursWorked)
% Function to compute the salary of a worker
% Extra hours are paid a 50% more
% wage = wage of the worker in euros
% hoursWorked = hours worker per week
% extra = extra salary of the worker per week
% salary = salary of the worker per week

base = wage * hoursWorked;
if (hoursWorked > 40)
    extra = (hoursWorked-40) * wage /2;
```

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Local Variables

```
salary = 0;  
yourWage = input('Introduce your wage');  
yourHours = input('Introduce the hours worked');  
yourSalary = obtainSalary(yourWage, yourHours);  
fprintf('Your salary is %d', yourSalary);  
fprintf('Value of salary %d', salary);
```

500

20

The *salary* variable of the script is not the same as the *salary* variable defined in the function body

```
function [salary]= obtainSalary(wage, hoursWorked)  
% Function to compute the salary of a worker  
% Extra hours are paid a 50% more  
% wage = wage of the worker in euros  
% hoursWorked = hours worker per week  
% extra = extra salary of the worker per week  
% salary = salary of the worker per week
```

MATLAB WORKSPACE

salary	yourWage	yourHours	yourSalary
0	500	20	10000

```
base = wage * hoursWorked;
```

```
(hoursWorked > 40)
```

```
extra = (hoursWorked-40) * wage / 2;
```

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Exercise

- Write a function called 'hypotenuse' that receives as parameters the lengths of two sides of a triangle and returns the value of the hypotenuse.
 - To compute the square root you can use the function *sqrt*

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Exercise

- Write a function called 'hypotenuse' that receives as parameters the lengths of two sides of a triangle and returns the value of the hypotenuse.

```
function [hyp] = hypotenuse(sideA, sideB)
% function hypotenuse
% Given the two sides of a triangle computes its
% hypotenuse
hyp = sqrt(sideA^2+sideB^2);
```

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Exercise

- Write a program that asks the user to introduce the length of two sides of the triangle, calls the hypotenuse function and prints the result on screen

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Exercise

- Write a program that asks the user to introduce the length of two sides of the triangle, calls the hypotenuse function and prints the result on screen

```
varSideA = input ('Introduce the lenght of one side');  
varSideB = input ('Introduce the lenght of the other side');  
varHypo = hypotenuse (varSideA, varSideB);  
fprintf('\n The hypthenuse is %d', varHypo);
```

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Exercise

- Write a function 'obtainSeconds' that receives as parameters three numbers representing hours, minutes and seconds and returns the total number of seconds.

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Exercise

- Write a function 'obtainSeconds' that receives as parameters three numbers representing hours, minutes and seconds and returns the total number of seconds.

```
function [totalseconds] = obtainSeconds(hours, minutes, seconds)
% function obtainSeconds
% Receives a number of hours, minutes and seconds and return
% the total number of seconds
totalseconds = hours*3600+minutes*60+seconds;
```

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Exercise

- Write a function 'obtainTime' that receives a number representing a total of seconds and returns the corresponding hours, minutes and seconds.
- Test the function writing a program that asks the user to introduce a number of seconds and prints on screen the corresponding hours, minutes and seconds.

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Exercise

PROGRAM

```
vtotalSeconds = input('Introduce seconds');  
[varHours, varMinutes, varSeconds] = obtainTime(vtotalSeconds);  
fprintf('Hours: %d \t Minutes: %d \t Seconds %d', varHours,  
        varMinutes, varSeconds);
```

Function

```
function [hours, minutes, seconds] = obtainTime(totalSeconds)  
  
hours = floor(totalSeconds / 3600);  
restSeconds = rem(totalSeconds, 3600);  
minutes = floor(restSeconds / 60);  
seconds = rem(restSeconds, 60);
```

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Exercise

- Write a function 'perfect' that receives a number and returns 1 (true) if the number is perfect and 0 if it is not. A number is perfect when the sum of its factors (excluding the number) is equal to its value.
 - Examples:
 - 6 is perfect as its factors are 1, 2 and 3 and $1+2+3 = 6$
 - 28 is perfect as $1+2+4+7+14 = 28$
 - Write a program that makes use of the function for printing on screen all the perfect numbers between 1 and 1000.

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Exercise (function)

```
function [ rdo ] = perfect( varNumber )
    sumFactors = 0;
    maxFactor = floor(varNumber/2);
    for i=1:maxFactor
        if rem(varNumber,i) == 0
            sumFactors = sumFactors + i;
        end;
    end;
    if (varNumber == sumFactors)
        rdo = 1;
    else
        rdo = 0;
    end;
end;
```

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Exercise (Program)

```
for i=1:1000
    if perfect(i) == 1
        fprintf('\n%d',i);
    end;
end;
```

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Exercise (Program)

```
for i=1:1000
    if perfect(i)
        fprintf('\n%d',i);
    end;
end;
```

This also works. Remember that perfect(i) is going to return 1 (true) or 0 (false)

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Remember

- Write each function in a separate file. Only one function per file
- The function and the file should have the same name
- Do not put a ; after the keyword *end* at the end of the function
- The variables in the function are local. You can't access them from the other functions or

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