POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Introduction to MATLAB

Calcoli di Processo dell' Ingegneria Chimica

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Resources

Books:

- G., Buzzi Ferraris; Manenti, Flavio. Fundamentals and Linear Algebra for the Chemical Engineer: Solving Numerical Problems.
- G., Buzzi Ferraris; Manenti, Flavio. Interpolation and Regression Models for the Chemical Engineer: Solving Numerical Problems.
- G., Buzzi Ferraris; Manenti, Flavio. Nonlinear Systems and Optimization for the Chemical Engineer: Solving Numerical Problems.
- G., Buzzi Ferraris; Manenti, Flavio. Differential and Differential-Algebraic Systems for the Chemical Engineer: Solving Numerical Problems.
- J. Nathan Kutz. Data-Driven Modeling and Scientific Computation.

- Steven L. Brunton; J. Nathan Kutz. Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control.
- A. Quarteroni; R. Sacco; F. Saleri; P. Gervasio. Matematica Numerica.
- A. Quarteroni; F. Saleri; P. Gervasio. Calcolo Scientifico: Esercizi e problemi risolti con MATLAB e Octave.
- D. Manca. Calcolo numerico applicato.

Online Material:

- Numerical Methods applied to chemical engineering (MIT).
- GitHub repository of the practical sessions.
- Matlab online tutorial and documentation.

Table of Contents

What is programming?

- The most simple answer is: “Programming is the **act** or activity of writing computer programs.”. In a more general way programming or coding is the act of writing a computer program.
- A **computer program** is a sequence of instructions that a computer is able to execute.
- **Computer** in the definition above is any device that is capable of processing code. This could be smartphones, ATMs, the Raspberry Pi, Servers to name a few.

Remember, every time we use smart devices, some code is running in the background. Moving a mouse pointer from one part of your computer screen to the other may seem like a simple task, but in reality, so many lines of code just ran. An act as simple as typing letters into Google Docs leads to lines of code being executed in the background. It’s all code everywhere.

The Natural Language of Computers

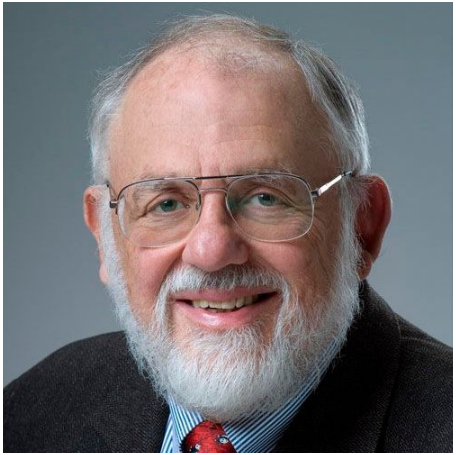
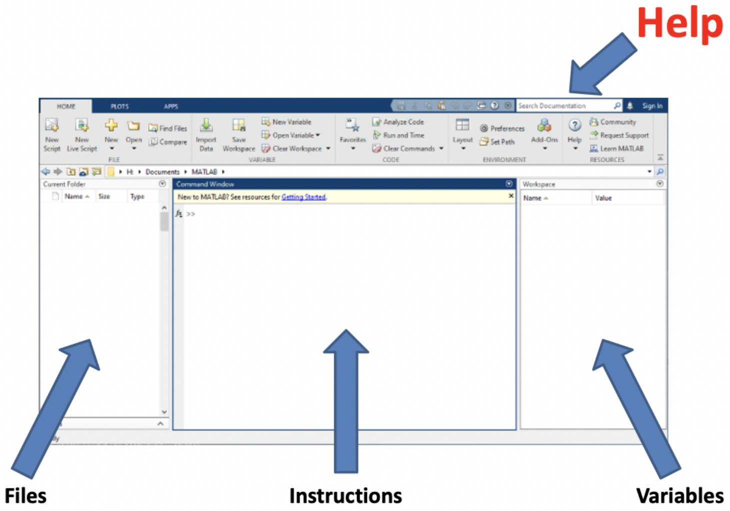


Figure 1: Cleve Barry Moler

The **only** language understood by a computer is the machine language. A very long list of 0 and 1. However it is a little bit inconvenient to write a series of zeros and ones. So (very smart) people, like the one in the picture, invented what are called programming languages (C/C++, Fortran, python, julia, MATLAB, ...).
N.B. Computers aren't very smart, the instructions need to be very precise! Telling a computer what you want it to do is sometimes hard because you have to explain things very carefully and precisely.

MATLAB


Help
HOME
PLOTS
APPS
Search Documentation
Sign In
New Script
New Live Script
New
Open
Find Files
Compare
FILE
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
VARIABLE
Favorites
Analyze Code
Run and Time
Clear Commands
CODE
Layout
Preferences
Set Path
Add-Ons
ENVIRONMENT
Help
Community
Request Support
Learn MATLAB
RESOURCES
Documents ▸ MATLAB ▸
Current Folder
Name
Size
Type
Command Window
New to MATLAB? See resources for Getting Started.
>>
Workspace
Name
Value
Files
Instructions
Variables

What can a Computer handle?

- MATLAB deals with numbers, arrays of numbers, characters, strings.
- Numbers can be of different types: signed and unsigned integers, and single-precision and double-precision floating-point numbers.
- When we set a variable value it gets stored as a series of 0 and 1 in a memory slot whose size depends on the type of variable (i.e., single-precision floating point numbers take 32 bits, or 4 bytes of memory, double precision 64 bit, or 8 bytes).
- By default, MATLAB store all values as double-precision floating point.

Area of a cylinder

Let's compute the area of a cylinder given the diameter D = 20 cm and height h = 50 cm.

Command window

```
>> D = 0.2 % m
>> h = 0.5 % m
>> perimeter = pi * D
>> Area = perimeter * h
```

Workspace

→ Generate variable D and assign value of 0.2

→ Generate variable h and assign value of 0.5

→ Generate variable perimeter and assign the result of the operation.

→ Generate variable Area and assign the result of the operation.

Source code: scripts and functions in MATLAB

Scripts are m-files (text format) containing MATLAB statements. MATLAB "functions" are another type of m-file. The biggest difference between scripts and functions is that functions have input and output parameters. Script files can only operate on the variables that are "hard-coded" into their m-file.

```
>> D = 0.2 % m
>> h = 0.5 % m
>> perimeter = pi * D
>> Area = perimeter * h
-----------------------------
ans = 0.3142
```

```
function Area = ComputeArea(D, h)
perimeter = pi * D;
Area = perimeter * h;
end
-----------------------------
>> ComputeArea(0.2, 0.5)
>> ans = 0.3142
```

Variables names

- MATLAB is case sensitive! **Pippo** $\neq$ **pippo**
- Variables name should be self explanatory, so prefer **distance, radius, ...** than **a, b, ...**
- When possible <u>use</u> the camel case notation to make stuff easier to read. **PipeLength, GasTemperature, ...**.

Arrays and Matrices

- In MATLAB **arrays** are defined as:

```
>> v = [5 13 97 31 98]
v =
5         13         97         31         98
```

- **Matrices** can be defined as a set of stacked arrays separated with ;

```
>> M = [5 13 97; 31 98 36; 11 9 20]
M =
5         13         97
31         98         36
11         9         20
```

- Elements can be accessed using their index (indices in MATLAB starts from 1)

```
>> v(1)
ans = 5
```

```
>> M(2,1) % (row number, column number)
ans = 31
```

Creating arrays and matrices

- Create a matrix of zeros or ones:

```
>> A = zeros(3,2)
A =
0       0
0       0
0       0
```

```
>> A = ones(2,3)
A =
1       1       1
1       1       1
```

- Create a vector of n equally spaced elements:

```
>> v1 = [1:2:11] % Parenthesis can be omitted
v1 =        1        3        5        7        9        11
```

```
>> v2 = [1:3:11] % Parenthesis can be omitted
v2   =          1            4            7            10   %   be   careful!
```

```
>> v3 = linspace(1,10,6) % Parenthesis can NOT be omitted!
v3 =        1.0        2.8        4.6        6.4        8.2        10.0
```

Operations with arrays and matrices

- Size of a matrix:

```
>> M = [1 2 3; 4 5 6]
>> size(M)
- - - - - - - - - - - - - - -
ans = 2 3
```

- Copying a matrix:

```
>> A = M
- - - - - - - - - - - - - - -
A =
1      2      3
4      5      6
```

- Copying a line or a column of a matrix:

```
>> v = M(1,:)
- - - - - - - - - - - - - - -
v =
1      2      3
```

- Size of an array:

```
>> size(v) ans = 1 3
- - - - - - - - - - - - - - -
>> length(v)
ans = 3
```

- Matrix transposition:

```
>> C = B'
-----------------------------
C =
1        4
2        5
3        6
```

- Element wise multiplication:

```
>> M .* M
-----------------------------
ans =
1        4        9
16       25       36
```

- Matrix multiplication:

```
>> M * B
-----------------------------
Error using * Inner matri-
ces dimensions must agree.
-----------------------------
>> M * C
-----------------------------
ans =
14       32
32       77
-----------------------------
size(M) = 2 3; size(C) = 3 2
```

Loops and conditional statements

for loop

- The **for** loop repeats a series of instructions a fixed number of times.

```
>> for i = 1:10
>>     paperino(i) = i
>> end
```

```
paperino = 1
paperino = 1 2
paperino = 1 2 3
...
paperino = 1 2 3 4 5 6 7 8 9
paperino = 1 2 3 4 5 6 7 8 9 10
```

- The index of the **for** loop can be changed by an arbitrary increment:

```
>> for i = 10:-1:1
>>     pluto(i) = i
>> end
```

```
pluto = 0 0 0 0 0 0 0 0 0 10
pluto = 0 0 0 0 0 0 0 0 9 10
pluto = 0 0 0 0 0 0 0 8 9 10
...
pluto = 0 2 3 4 5 6 7 8 9 10
pluto = 1 2 3 4 5 6 7 8 9 10
```

Examples

- Sum the first hundred natural numbers.

$$\sum_{i=1}^{100} i = ?$$

- Sum hundred times one.

$$\sum_{i=1}^{100} 1 = ?$$

```
>> sum = 0;
>> for i = 1:100
>>     sum = sum + i;
>> end
>> disp(sum);
```

```
>> sum = 0;
>> for i = 1:100
>>     sum += 1;
>> end
>> disp(sum);
```

while loop

- The **while** loop repeats a series of instructions until a condition is TRUE.
- N.B. pay attention with the while loop it can run till infinite, handle with care.

```
>> sum = 0;
>> while (sum < 325)
>>     token = token + 1
>>     sum = sum + token;
>> end
disp(["Iteration number: ", num2str(token)]);
disp(["Sum is equal to: ", num2str(sum)]);
```

```
Iteration number: 25
Sum is equal to: 325
```

IF Statement

- The IF statement executes a series of instructions only IF a condition is TRUE:

```
if (condition)
... instructions
elseif (condition)
... instructions
elseif (condition)
... instructions
else
... instructions
end
```

Example: Write a simple script to compute the absolute value of a number.

```
>> x = 35
>> if (x≥0)
>>     abs = x;
>> else
>>     abs = -x
>> end
```

Functions and Plot

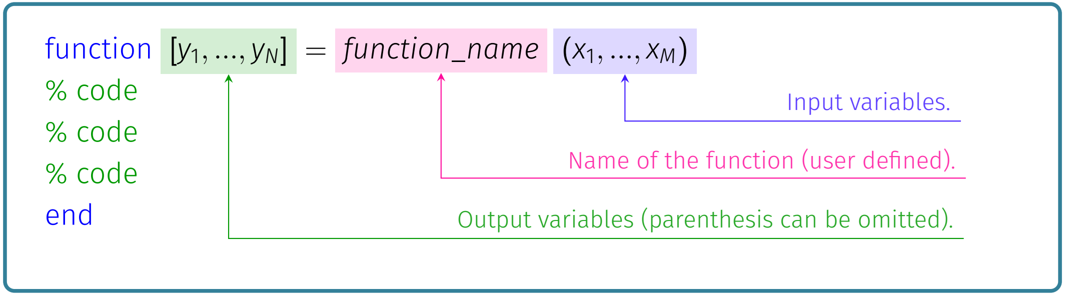
Functions

In MATLAB, a function is a block of code that takes inputs, performs a set of operations, and returns outputs. Functions allow you to organize code in a clearer and more reusable way, especially when you need to perform the same operation in different parts of your program.

Why using functions?

- **Modularity**: Separating code into functions makes the program more readable and easier to maintain.
- **Reusability**: A function can be reused in different parts of the program without rewriting the code.

Syntax



$$\text{function } [y_1, \ldots, y_N] = \mathit{function\_name}\,(x_1, \ldots, x_M)$$

```
% code
% code
% code
end
```

Input variables.

Name of the function (user defined).

Output variables (parenthesis can be omitted).

Plot

Let’s plot on a Cartesian plane the following function:

$$y(x) = 3x + 2$$

```
x = 0:1:20
for i = 1:length(x)
y(i) = 3 * x(i) + 2;
end
plot(x, y)
```

Now let's add to the previous plot the following function:

$$y(x) = -3x + 4$$

```
x = 0:1:20
for i = 1:length(x)
y1(i) = 3 * x(i) + 2;
y2(i) = -3 * x(i) + 4;
end
hold on
plot(x, y)
plot(x, y2)
```

Exercises

Example

Let’s define a square matrix populated with random numbers, using the function **magic()** and loop over its rows and columns to match specific conditions.

```
>> clear, clc
>> M = magic(300);
>> for (i = 1:300)
>>     for (j = 1:300)
>>         if(M(i,j) == 569)
>>             disp('Found!')
>>         end
>>     end
>> end
```

The babilonian method

Write a function that implements the Babilonian method to compute the square root of a number with a precision of four decimal figures.

1. **Make an Initial guess**. Guess any positive number x_0.
2. **Improve the first guess**. Apply the formula $x_1 = \frac{x_0 + \frac{S}{x_0}}{2}$. The number x_1 is a better approximation to $\sqrt{S}$.
3. **Iterate until convergence**. Apply the formula $x_{n+1} = \frac{x_n + \frac{S}{x_n}}{2}$ until the convergence is reached.

Convergence is reached when the digits of x_{n+1} and x_n agree to as many decimal places as you desire.

```
>> function SquareRoot = ComputeSquareRoot(S)
>>     iter = 0;
>>     x0 = S;
>>     y = 0.5*(x0+S/x0);
>>     while abs(x0-y)>1e-5 && iter<50
>>         x0 = y;
>>         y = 0.5*(x0+S/x0);
>>         iter = iter+1;
>>     end
>>     disp(['Number of iteration to reach convergence: ', num2str(iter)])
>>     SquareRoot = y;
>> end
```

Useful material

Useful Functions

- **clc**: clear the screen of the command window.
- **clear / clear all**: erase all the variables contained inside the workspace.
- **close / close all**: close all the pop-up windows opened after plotting something.
- **disp(variable name)**: print inside the command window the value of a certain variable.
- **fprintf(...)**: same function of “disp” with a slight different behaviour.
- **magic(n)**: is an n-by-n matrix constructed from the integers 1 through n^2 with equal row, column, and diagonal sums. Produces valid magic squares for all $n > 0$ except $n = 2$.
- **rand(n)**: returns an n-by-n matrix of uniformly distributed random numbers.

Line Style	
’-’	Solid Line
’–’	Dashed Line
’:’	Dotted Line
’-.’	Dashed Dotted Line
Marker	
’o’	Circle
’+’	Plus
’*’	Asterisc
’.’	Point
’x’	Cross
’-’	Horizontal line
’|’	Vertical line
’s’	Square
’d’	Diamond
’^’	Upward-pointing triangle
’v’	Downward-pointing triangle
’>’	Right-pointing triangle
’<’	Left-pointing triangle
’p’	Pentagram
’h’	Hexagram

Thank you for the attention!