MATLAB
An Introduction

2015 BRAZIL STUDY ABROAD PROGRAM

TEXAS A&M UNIVERSITY- UNIVERSITY OF SAO PAULO

ELMER ALEXIS GAMBOA PEÑALOZA

RODOLPHO VILELA ALVES NEVES

RAFAEL FERNANDO QUIRINO MAGOSSI

MICHEL BESSANI

DEPARTAMENTO DE ENGENHARIA ELÉTRICA USP - SÃO CARLOS

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Why Matlab?

Friendly environment

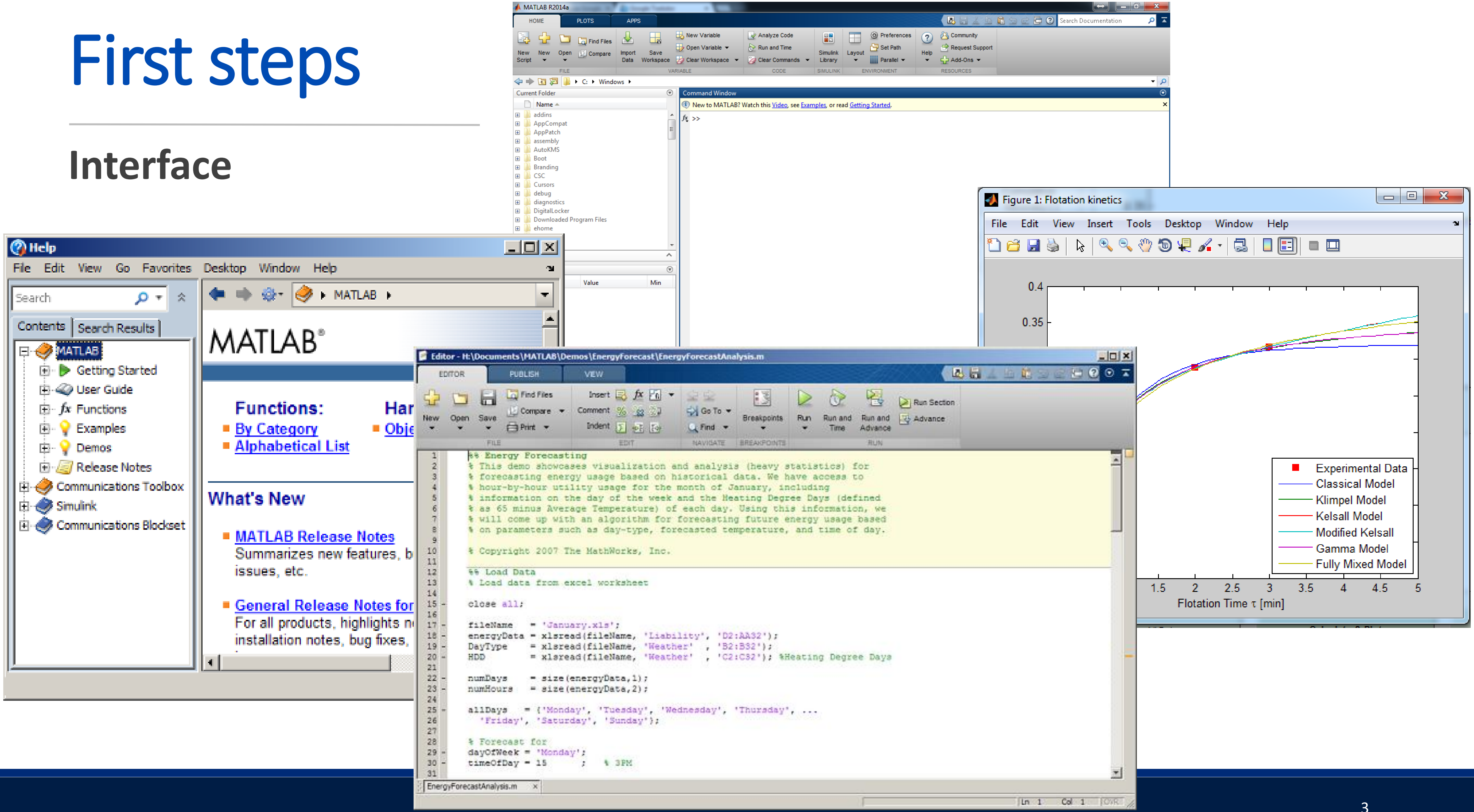
Simple programming language

Lots of tools

Can be applied in several areas of knowledge

First steps

Interface



First steps

Programming language

```
>> a = 1+1
>> b = [1, 1, 2, 3, 5, 8, 13, 21]
>> x = a+b
x =
  3, 3, 4, 5, 7, 10, 15, 23
```

First steps

Matlab’s tools

- Vectors and matrices
- Plotting and graphics
- Symbolic calculus
- Differential equations
- Transforms
- Model fitting
- Simulink
- A lot of other tools…

Hands on!

Try calculating those math operations:

$$5\left(\frac{3}{4}\right)+\frac{9}{5} \quad = 5.55$$

$$4^3\left(\frac{3}{4}-\frac{9}{2*3}\right)=-48$$

Hands on!

Find the volume of a beer can (consider the can as a cylinder):

The volume of a beer can be calculated by:

$$V = \pi r^2 h$$

r = 3 cm

h = 12.5 cm

Hands on!

```
>> r = 3;
>> h = 12.5;
>> V = pi*3^2*12.5
V =
    353.4292
```

Other operators

Natural logarithm

```
>> log(a);
```

Base ten log

```
>> log10(a);
```

Exponential:

```
>> exp(a);
```

Trigonometric functions

```
>> cos(pi);
>> sin(pi);
>> tan(pi);
>> acos(pi);
>> asin(pi);
>> atan(pi);
```

Complex numbers

```
>> y = 5i;
>> z = 1+3*i;
>> w = 3j;
```

Script file

Using script files, it’s possible to save the work for later use or for recording data

It’s very useful when there is a long sequence of operations

Let’s create a script file:

- File -> New -> Script
- Or click on the New file icon on the toolbar at the top of the screen

Script file

Type in the script file:

```
% Example 1: Using script file
x = [1,2,3,4];
y = exp(x)
```

Save the file as *example1.m*

Script file

At the command window, type:

```
>> example1
```

Vector and Matrices

When you work with data, you need to handle them sometimes.

Vectors are one-dimensional arrays.

```
>> a = [1, 2, 3]
a =

1  2  3
```

```
>> a = [1; 2; 3]
a =
      1
      2
      3
```

```
>> a’
=
      1  2  3
```

Vector and Matrices

Matlab allows you to append vectors together to create new ones.

Let **u** and **v** be two column vectors *m* and *n* respectively.

What happens if I type:

```
>> w = [u; v]
```

Vector and Matrices

```
>> w = [u; v];
>> size(w)
ans =
     m+n
```

The same works for row vectors as well

Vector and Matrices

It is possible to create uniformly spaced vector using colons:

```
>> t = [0:10]
t =
0    1    2    3    4    5    6    7    8    9    10
```

Vector and Matrices

You can also change the step size of the vector using the syntax:

```
>> t = [0:2:10]
t =
 0    2    4    6    8    10
```

Hands on!

Using a script file, try to create a time vector **t** from 0 to 10 using 1 as step size. Then, create a vector **y = 1-exp(-t)**.

After that, create an vector **t2** from 0 to 10 using 0.1 as step size and a vector **y2 = 1-exp(-t2)**.

Hands on!

First, the vector t:

```
>> t = [0:10];
```

Then, the vector y:

```
>> y = 1-exp(-t);
```

The vector t2 and y2:

```
>> t2 = [0:0.1:10]; y = 1-exp(-t2);
```

Hands on! (Plus)

Using the command *plot*, try to plot txy and t2xy2 in the same figure.

Tips:

The syntax for plot is plot(**a**,**b**).

a and **b** must be the same length.

You can plot more than one couple using the syntax (**a,b,c,d**).

Extracting information of the vectors

There are several commands to get information from vectors.

Some examples are:

```
>> f = [1 4 -6 3 7 9 -2 6 3 -7...
4 9 19];

>> length(f)

ans =

   13

>> max(f)

ans =

   19

>> min(f)

ans =

   -7
```

Extracting information of the vectors

First of all, we need the dot product of the vector v.

Let's define v = [4 6 9].

The array product of v is given by:

```
>> v.*v
 ans =
 16     36     81
```

Extracting information of the vectors

Then, we need to sum the dot product of the vector v:

```
>> a = sum(v.*v)
a =
    133
```

The magnitude of v is the square root of a.

```
>> mag = sqrt(a)
mag =
    11.5325
```

Operation with matrices

A matrix is a two-dimensional array of numbers. To create a matrix in Matlab, we enter each row as a sequence of comma (or space), and then use semicolons to mark the end of each row.

For example:

```
>> A = [1, 4; 5   2]

A =

    1    4

    5    2
```

```
>>2*A

ans =

    2     8

    10    4
```

Operation with matrices

If two matrices have the same size, we can add or subtract them:

```
>> B = [1 3; -1 -4];
>> A+B
ans =
    2    7
    4   -2
```

Operation with matrices

We can also compute the transpose of a matrix. The transpose operation switch the rows and columns in a matrix.

```
>> A’

ans =

    1    5

    4    2
```

Operation with matrices

If the matrix contains complex elements, the transpose will compute the conjugates:

```
>> C = [1+i, 4-i; 5+2i, 3-3i]
C =
    1+1i    4-I
  5+2i    3-3i
```

```
>> C’
ans =
    1-1i      5-2i
    4+i       3+3i
```

Operation with matrices

If you want to compute the transpose of a matrix with complex elements without computing the conjugate, you use (.’):

```
>> C.’
ans =
    1+1i     5+2i
     4-i     3-3i
```

Operation with matrices

The array multiplication works with matrix as well. It is important to recognize that this is not matrix multiplication.

```
>> A = [1, 4; 5   2]; B = [1 3; -1 -4];
>> A.*B
ans =
    1    12
   -5    -8
```

Matrix multiplication

Let's consider two matrices:

```
>> C = [2, 1; 1, 2]; D = [3, 4; 5, 6];
```

The multiplication between them will be:

```
>> C*D
ans =
    11    14
    13    16
```

Special matrix types

The identify matrix is a square matrix that has ones along the diagonal and zeros elsewhere. To create a n-order identify matrix, type:

```
>> eye(n);
>> eye(2)
ans =
    1    0
    0    1
```

Special matrix types

To create a matrix of zeros, type:

```
>> zeros(n)         % n-order matrix of zeros
>> zeros(m,n)    % mxn matrix of zeros
```

To create a matrix of ones, type *ones(n)* or *ones(m,n)*.

Referencing matrix elements

Individuals elements and columns in a matrix can be referenced using Matlab. Consider the matrix:

```
>> A = [1 2 3; 4 5 6; 7 8 9]

A =

     1     2     3

     4     5     6

     7     8     9
```

Referencing matrix elements

We can pick out the element at row position m and column position n by typing *A(m,n)*.

For example:

```
>> A(2,3)
ans =
     6
```

Referencing matrix elements

To reference all elements in the *ith* column, we write *A(:,i)*.

```
>> A(:,2)
ans =
   2
   5
   8
```

Referencing matrix elements

To pick out the elements in the *ith* through *jth* column, we type *A(:,i:j)*.

```
>> A(:,2:3)
ans =
  2    3
  5    6
  8    9
```

Referencing matrix elements

We can pick out pieces or sub matrices as well.

```
>> A(2:3,1:2)
ans =
    4   5
    7   8
```

Referencing matrix elements

We can change the value of matrix elements using these references as well.

```
>> A(1,1) = -8

ans =

   -8    2    3

    4    5    6

    7    8    9
```

Three-Dimensional Plots

```
plot3(x,y,z,'line specifiers','PropertyName',property value)
```

x, y, and z are vectors of the coordinates of the points.

(Optional) Specifiers that define the type and color of the line and markers.

(Optional) Properties with values that can be used to specify the line width, and marker's size and edge and fill colors.

Hands on!

example, if the coordinates x, y, and z are given as a function of the parameter
t by:

$$x = \sqrt{t} * \sin(2*t)$$

$$y = \sqrt{t} * \cos(2*t)$$

$$z = 0.5*t$$

For $0 \leq t \leq 6*\pi$

Using the command *plot3*, try to plot tx(x,y,z) in the same figure.

Hands on!

```
t=0:0.1:6*pi;
x=sqrt(t).*sin(2*t);
y=sqrt(t).*cos(2*t);
z=0.5*t;
plot3(x,y,z,'k','linewidth',1)
grid on
xlabel('x'); ylabel('y'); zlabel('z')
```

Determinants and Linear Systems

To calculate the determinant of a matrix A in Matlab, simply write det(A).

For example:

```
>> A = [1 3; 4 5]; det(A)
ans =
-7
```

Determinants and Linear Systems

Consider the following set of equations:

$$5x+2y-9z=44$$
$$-9x-2y+2z=11$$
$$6x+7y+3z=44$$

To find a solution to a system of equations like this, we can use two steps.

Determinants and Linear Systems

First, we find the determinant of the coefficient matrix A:

$$A = \begin{pmatrix} 5 & 2 & -9 \\ -9 & -3 & 2 \\ 6 & 7 & 3 \end{pmatrix}$$

```
>> A = [5 2 -9; -9 -3 2; 6 7 3]; det(A)
ans =
368
```

When the determinant is nonzero, a solution exists. This solution is the column vector:

$$X = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

Determinants and Linear Systems

Matlab allows us to generate the solution readily using left division. First we need create a column of the numbers on right-hand side of the system. We find:

```
>> b = [44; 11; 5];
>> A\b
ans =
[-5.1250 7.6902 -6.0272]'
```

Determinants and Linear Systems

Another way to solve linear system problems is check the rank of the system. Let's consider the linear system of equations with **m** equations and **n** unknowns:

$$\mathbf{Ax=b}$$

The augmented matrix is formed by concatenating the vector **b** onto the matrix **A**.

$$[\mathbf{A}\ \mathbf{b}]$$

Determinants and Linear Systems

The system has a solution if and if only rank(**A**) = rank([**A b**]). If the rank is equal to **n**, then the system has a unique solution.

If rank(**A**) = rank([**A b**]) but the rank < **n**, there are infinite number of solutions. If we denote the rank by **r**, then **r** of the unknown variables can be expressed as linear combination of **n**-**r** the other variables.

Determinants and Linear Systems

To compute the rank of a matrix, you can use the Matlab command rank(**A**), for example.

```
>> rank(A);
```

Hands on!

Let’s consider the linear system

$$x-2y+z=12$$
$$3x+4y+5z=20$$
$$-2x+y+7z=11$$

Find the solution using the Matlab command *rank* and the left division.

Inverse and pseudoinverse of a matrix

Matlab has commands to compute the inverse and pseudoinverseof a matrix. The syntax is:

```
>> A = [1, 2; 3, 4];
>> inv(A); %For inverse of the matrix A
>> pinv(A); %For the pseudoinverse of the matrix A
```

Decomposition of a matrix

Matlab can computes the LU decomposition of a matrix using the command *lu*.

```
>> A = [1 2 3; 3 2 1; 7 5 11]; b = [4; 2; -1];

>> [L,U] = lu(A);
```

L =

0.1429 1.0000 0

0.4286 -0.1111

1.0000

1.0000 0 0

U =

7.0000 5.0000 11.0000

0 1.2857 1.4286

0 0 -3.555659

Decomposition of a matrix

Matlab can computes the LU decomposition of a matrix using the command *lu*.

```
>> A = [1 2 3; 3 2 1; 7 5 11]; b = [4; 2; -1];

>> [L,U] = lu(A);
```

```
L =
    0.1429    1.0000         0
    0.4286   -0.1111    1.0000
    1.0000         0         0

U =
    7.0000    5.0000   11.0000
         0    1.2857    1.4286
         0         0   -3.5556
```

Decomposition of a matrix

To solve the linear system, you need to solve the equation:

$$x\text{=}U\backslash(L\backslash \mathrm{b})$$

```
>> x = U\(L\b)
x =
-1.8125
4.1250
-0.8125
```

Checkpoint

Let´s put our hands on practical programming things.
Go to EESC Moodle’s website and download the file Checkpoint 1.pdf

References

[1] Matlab Product Help.

[2] Matlab Demystified. A Self-Teaching Guide, David McMahon, McGraw Hill.

[3] Matlab: An Introduction with Applications, Amos Gilat, Fourth Edition, JOHN WILEY & SONS.