OKLAHOMA STATE UNIVERSITY

ECEN 4413 - Automatic Control Systems

Matlab Lecture 1
Introduction and Control Basics

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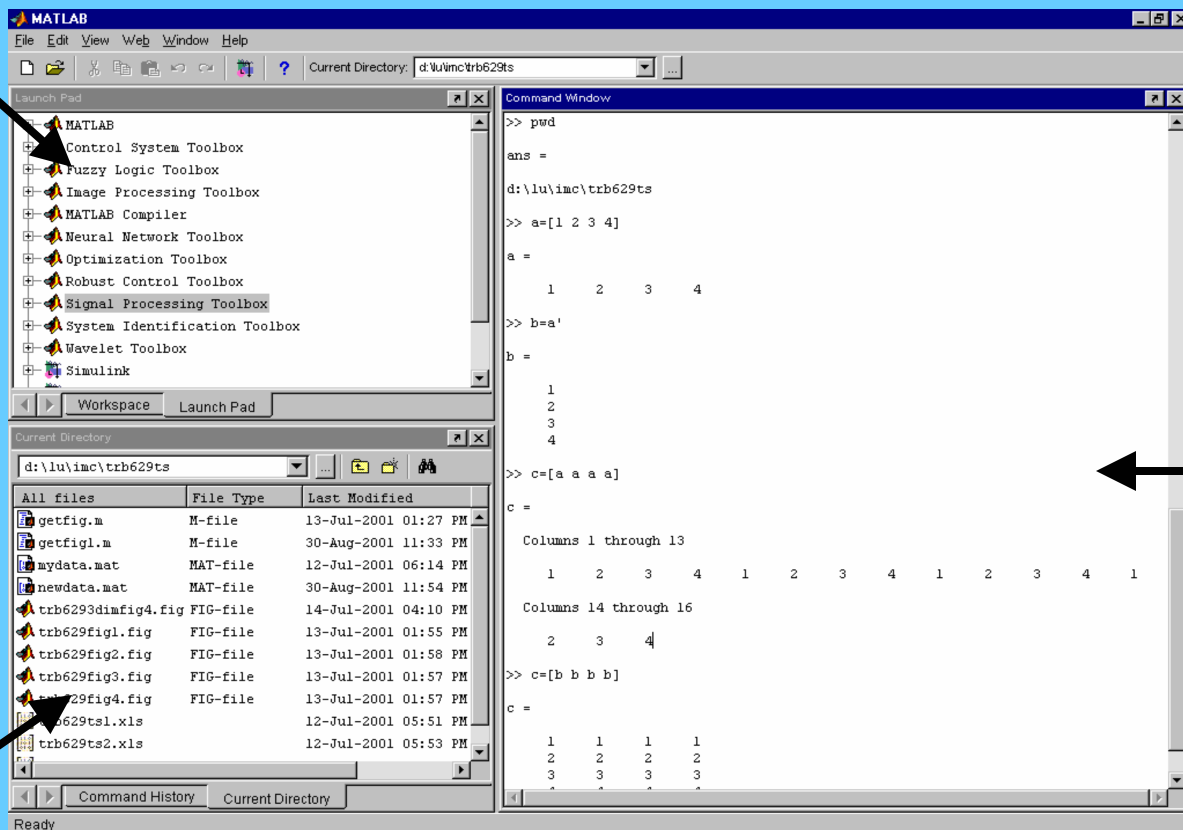
What is Matlab?

- Invented by Cleve Moler in late 1970s to give students access to LINPACK and EISPACK without having to learn Fortran.
- Together with Jack Little and Steve Bangert they founded Mathworks in 1984 and created Matlab.
- The current version is 7.
- Interpreted-code based system in which the fundamental element is a matrix.

The Interface

Workspace and Launch Pad



Command Window

Command History and Current Directory

Variable assignment

- Scalar: a = 4
- Vector: v = [3 5 1] ⟹ $v = \begin{bmatrix} 3 & 5 & 1 \end{bmatrix}$

  v(2) = 8 ⟹ $v = \begin{bmatrix} 3 & 8 & 1 \end{bmatrix}$

  t = [0:0.1:5] ⟹ $t = \begin{bmatrix} 0 & 0.1 & 0.2 & \cdots & 4.9 & 5 \end{bmatrix}$

- Matrix: m = [1 2 ; 3 4] ⟹ $m = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$

  m(1,2)=0 ⟹ $m = \begin{bmatrix} 1 & 0 \\ 3 & 4 \end{bmatrix}$

Basic Operations

- Scalar expressions

b = 10 / (sqrt(a) + 3) ⟹ $b = \frac{10}{\sqrt{a} + 3}$

c = cos (b * pi) ⟹ $c = \cos(b\pi)$

- Matrix expressions

n = m * [1 0]’ ⟹ $n = \begin{bmatrix} 1 & 0 \\ 3 & 4 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 3 \end{bmatrix}$

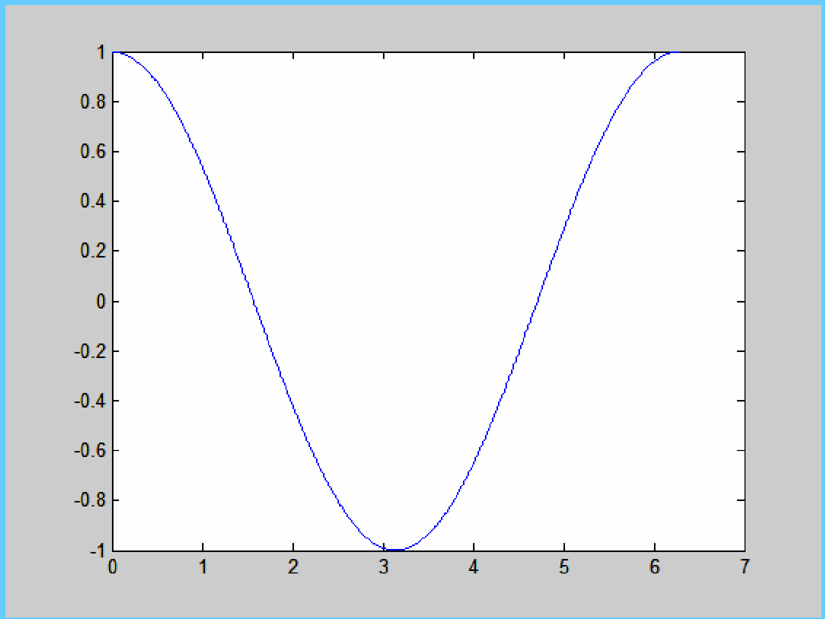
Useful matrix operations

- Determinant: **det**(m)
- Inverse: **inv**(m)
- Rank: **rank**(m)
- i by j matrix of zeros: m = **zeros**(i,j)
- i by j matrix of ones: m = **ones**(i,j)
- i by i identity matrix: m = **eye**(i)

Example

- Generate and plot a cosine function

```
x = [0:0.01:2*pi];
y = cos(x);
plot(x,y)
```



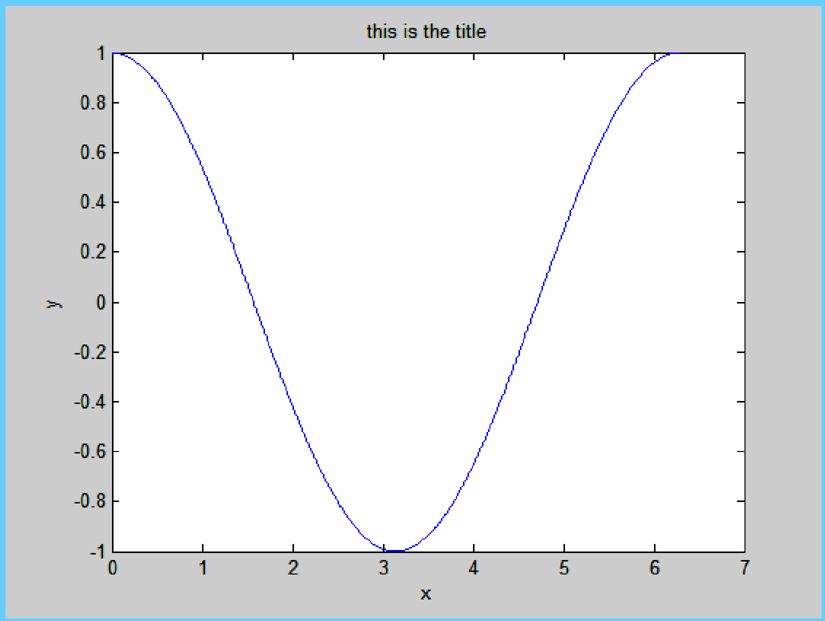
Example

- Adding titles to graphs and axis

title('this is the title')

xlabel('x')

ylabel('y')



Adding graphs to reports

- Three options:

  1) Print the figure directly

  2) Save it to a JPG / BMP / TIFF file and add to the report (File → Export…)

  3) Copy to clipboard and paste to the report (Edit → Copy Figure) *

* The background is copied too! By default it is gray. To change the background color use:

```
set(gcf,'color','white')
```

The .m files

- Programming in Matlab is done by creating “.m” files.

    File → New → M-File

- Useful for storing a sequence of commands or creating new functions.

- Call the program by writing the name of the file where it is saved (check the “current directory”)

- “%” can be used for commenting.

Other useful information

- help <function name> displays the help for the function

  ex.: **help** plot

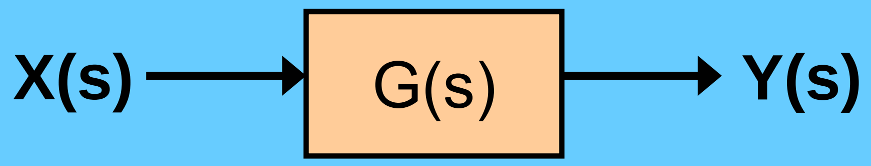
- helpdesk brings up a GUI for browsing very comprehensive help documents

- **save** <filename> saves everything in the workspace (all variables) to <filename>.mat.

- **load** <filename> loads the file.

Using Matlab to create models

- Why model?
  - Represent
  - Analyze
- What kind of systems are we interested?
  - Single-Input-Single-Output (SISO)
  - Linear Time Invariant (LTI)
  - Continuous



Model representations

Three Basic types of model representations for continuous LTI systems:

- **Transfer Function representation (TF)**
- **Zero-Pole-Gain representation (ZPK)**
- **State Space representation (SS)**

! More help is available for each model representation by typing:

help ltimodels

Transfer Function representation

Given: $G(s) = \dfrac{Y(s)}{U(s)} = \dfrac{25}{s^2 + 4s + 25}$

Matlab function: **tf**

Method (a)	Method (b)

`num = [0 0 25];`
`den = [1 4 25];`
`G = tf(num,den)`
	`s = tf('s');`
	`G = 25/(s^2 +4*s +25)`

Zero-Pole-Gain representation

Given: $H(s) = \frac{Y(s)}{U(s)} = \frac{3(s-1)}{(s-2+i)(s-2-i)}$

Matlab function: **zpk**

```
zeros = [1];
poles = [2-i 2+i];
gain = 3;
H = zpk(zeros,poles,gain)
```

State Space representation

Given: $\begin{cases} \dot{x} = Ax + Bu \\ y = Cx + Du \end{cases}$, $A = \begin{bmatrix} 1 & 0 \\ -2 & 1 \end{bmatrix}$ $B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

$C = \begin{bmatrix} 3 & -2 \end{bmatrix}$ $D = \begin{bmatrix} 0 \end{bmatrix}$

Matlab function: **ss**

```
A = [1 0 ; -2 1];
B = [1 0]';
C = [3 -2];
D = [0];
sys = ss(A,B,C,D)
```

System analysis

- Once a model has been introduced in Matlab, we can use a series of functions to analyze the system.

- Key analyses at our disposal:

  1) Stability analysis

     e.g. pole placement

  2) Time domain analysis

     e.g. response to different inputs

  3) Frequency domain analysis

     e.g. bode plot

Stability analysis

Is the system stable?

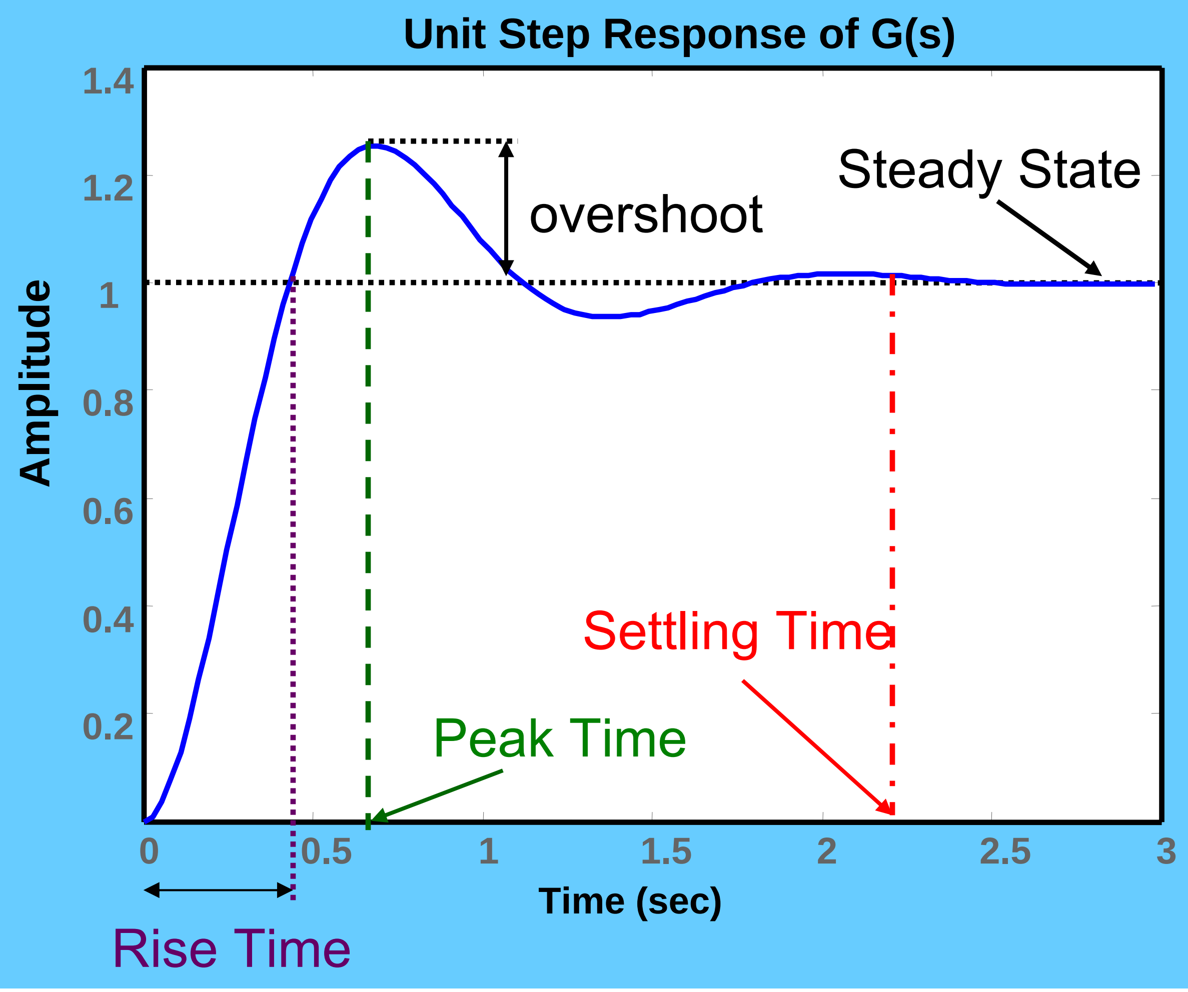
Recall: All poles of the system must be on the right hand side of the S plain for continuous LTI systems to be stable.

Manually: Poles are the roots for the denominator of transfer functions or eigen values of matrix A for state space representations

In Matlab: **pole**(sys)

Time domain analysis

Once a model has been inserted in Matlab, the step response can be obtained directly from: **step**(sys)



Time domain analysis

Matlab also caries other useful functions for time domain analysis:

- Impulse response

```
impulse(sys)
```

- Response to an arbitrary input

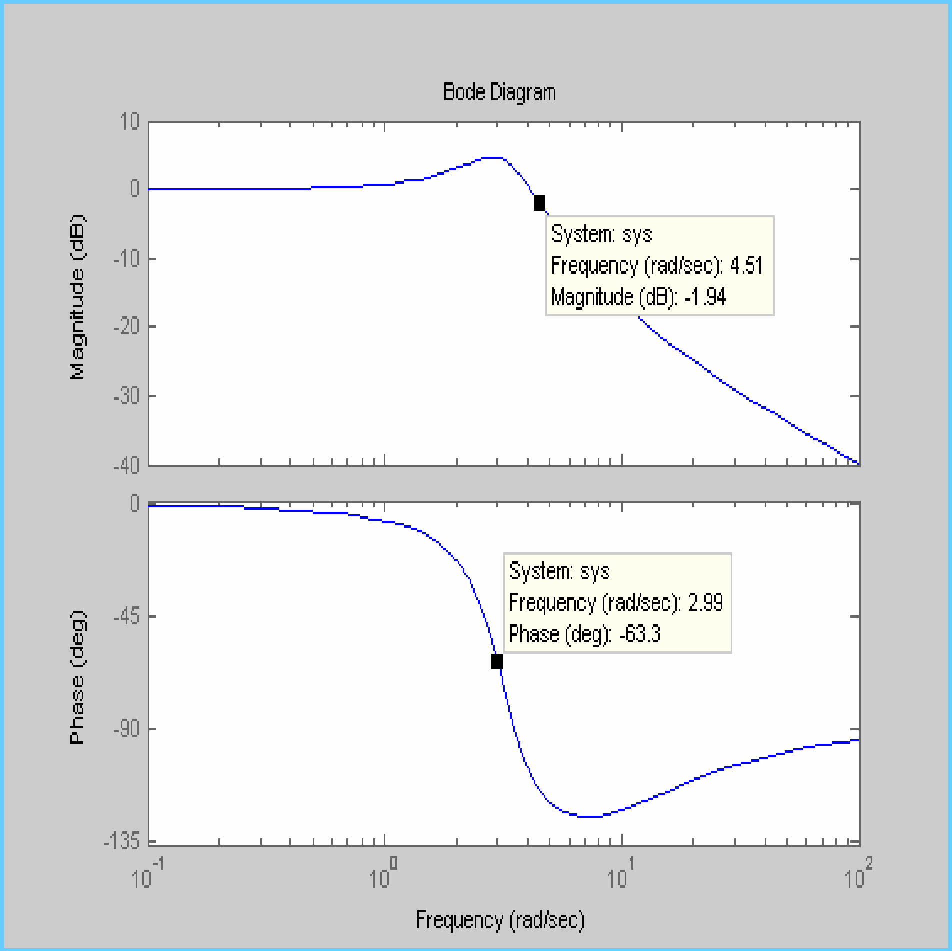
  e.g.

```
t = [0:0.01:10];
u = cos(t);
lsim(sys,u,t)
```

! It is also possible to assign a variable to those functions to obtain a vector with the output. For example: `y = impulse(sys);`

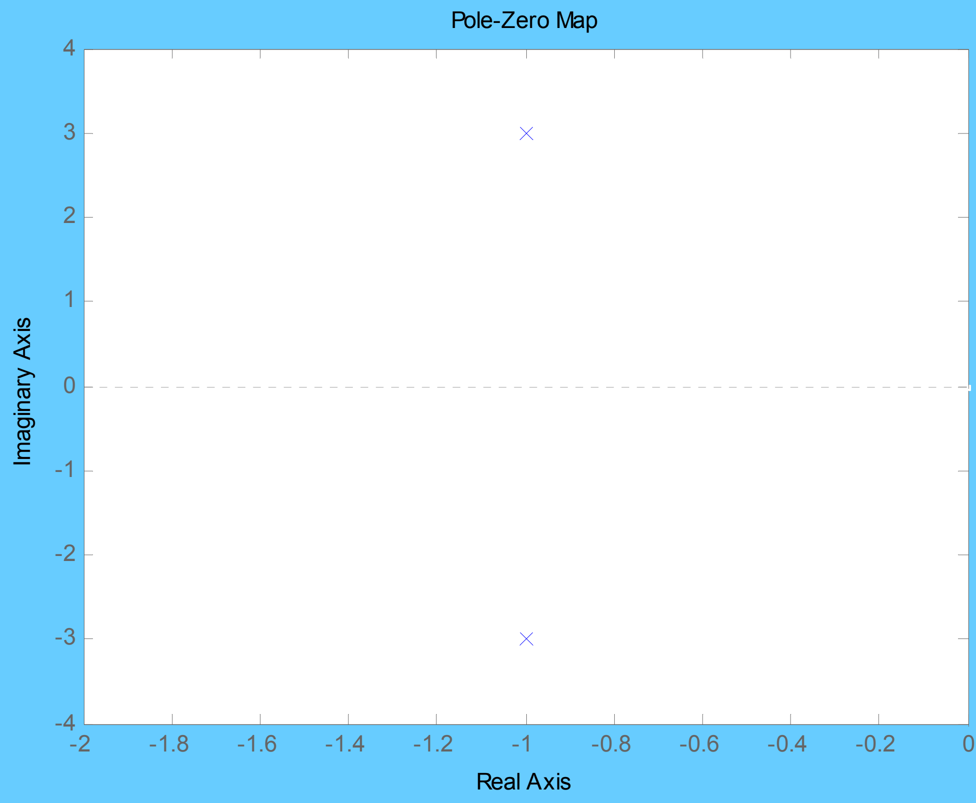
Frequency domain analysis

Bode plots can be created directly by using: **bode**(sys)



Frequency domain analysis

For a pole and zero plot: **pzmap**(sys)



Extra: partial fraction expansion

Given:

$$G(s) = \frac{2s^2 + 3s + 2}{s^2 + 3s + 2}$$

```
num=[2 3 2];
den=[1 3 2];
[r,p,k] = residue(num,den)

r =
   -4
    1
p =
   -2
   -1
k =
    2
```

$\Rightarrow$

Answer:

$$G(s) = k(s) + \frac{r(1)}{s - p(1)} + \cdots + \frac{r(n)}{s - p(n)}$$

$$= 2s^0 + \frac{-4}{s-(-2)} + \frac{1}{s-(-1)}$$