TAMPERE UNIVERSITY OF TECHNOLOGY

SGN-1158 Introduction to Signal Processing, short version

Lecture: Introduction to DSP simulations in MATLAB

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- Why you’re at this lecture/lab?
- Do not fear MATlab. It’s your friend
- MATlab is a tool
- Where I can use MATlab? Examples
- I’m afraid of program languages…

- **THE MAIN IDEA OF THE LECTURE**

Contents

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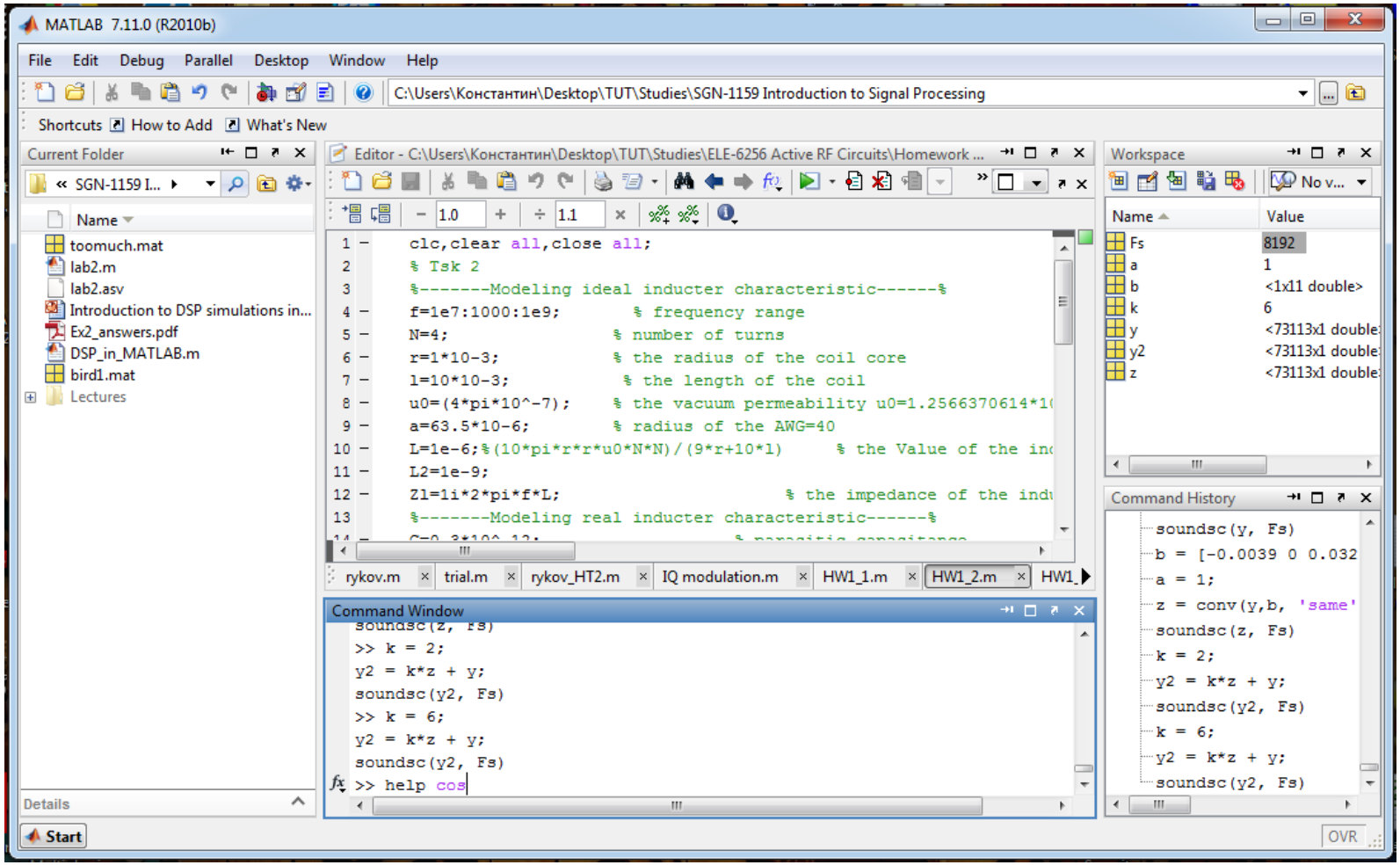
DISCRETE SIGNALS IN MATLAB

- Sequences
- Unit sample sequence, unit step sequence, discrete exp
- Discrete complex harmonic signal
- Functions max, sum and prod
- Generation of signals: rectpuls, tripuls, gauspuls, sinc, square, sawtooth, diric
- Functions rand(1,N) and randn(1, N)

- **TASK: Open MATLAB**

BASICS OF MATLAB

The main MATLAB window



Some basic hints

- `help <name>` (for example: `>> help cos`)
- *`;` blocks automatically output of the variables*
- *`%` makes a comment*
- *to comment a few rows hold* Ctrl+R
- *to uncomment a few rows* Ctrl+T
- *Always use:* `clc,clear all; close all;`

TASK

- *Type in Editor:*
- `================`
- `My MATlab Crib`
- `================`
- *Use CTRL+R to comment it*
- `clc; clear all; close all;`

Main MATLAB objects

- *Commands* (`clc, help, demo`)
- *Constants* (`10, -17.28, 5+3j, 1e-6, 10^2`)
- *Standard const* (`pi, 1i, eps`)
- *Variables – MATlab object, which might change it's value during simulation. All variables are MATRIXES in MATlab*
- *Functions* (`sin(X), exp(X), log10(X), sqrt(X), abs(X), real(X), imag(X)`)
- *Expressions – is a sum of constants, functions, variables, which are summed by operational symbols* (`x+sin(a)-sqrt(pi);`)

Main operation symbols

Symbol	Operation
+	Summation
–	Difference
*	Multiplication of matrixes
.*	Multiplication of elements
/	Right division
.'	Transposing

MATLAB IS AN ADVANCED CALCULATOR

Complex numbers

Use MATLAB as calculator to find answers

$$\frac{3}{7} - \frac{10}{15} \qquad \sqrt[4]{5^7} \qquad (3+4i)(5-6i)$$

$$\frac{3+4i}{5-6i} \qquad (2+3i)^2 \qquad \sqrt{5}e^{i\pi/4}$$

Use `help` *to find what these commands do*

- `abs`
- `angle`
- `exp`
- `conj`

Type and simulate

- `z=3+4i`
- `r=abs(z)`
- `fii=angle(z)`
- `r*exp(i*fii)`
- `zk=conj(z)`
- `z*zk-r^2`

- *What the command* `format` *does?*

Vectors

- Type `a=[2 4 5 7]` and `b=[-1 4 -2 1]`
- Find `a+b, 2*a-2*b`
- What happens if you type `a'` and `b'`
- `a*b; a'*b; a*b'; a'*b';`
- `-1:10; 0:2:100; 1:-0.25:-2`
- Form vectors `a=(7,8,9,…,22); b=(0,2,4,…,100);`
  `c=(100,95,90,…,35)`
- What did you get `a(3)? a([3 5 7])? a(3:7)? a(3:end)?`

Matrices

$$A = \begin{bmatrix} -7 & 5 & -9 \\ 2 & -1 & 2 \\ 1 & -1 & 2 \end{bmatrix} \Rightarrow$$

```
A=[-7 5 -9; 2 -1 2; 1 -1 2];
```

$$B = \begin{bmatrix} 16 & 3 & 2 & 13 \\ 5 & 10 & 11 & 8 \\ 9 & 6 & 7 & 12 \\ 4 & 15 & 14 & 1 \end{bmatrix}$$

$$D = \begin{bmatrix} 6 & 3 & 2 \\ 2 & 12 & -7 \\ -1 & 6 & 2 \\ -5 & 15 & 11 \end{bmatrix}$$

$$C = \begin{bmatrix} 4 & 2 & -3 \\ 7 & -7 & 9 \\ 3 & -5 & 6 \end{bmatrix}$$

Task

- Calculate: 3A-5C, 7A+2B, CA, CD'
- Find out commands: zeros(n), zeros(m,n), ones(n), ones(m,n), size(D), zeros(size(D)), diag([1 2 3 4]), eye(n)
- What happens `[A,B]` and `[A;B]`?
- Try to find an easy way to build a 7*8-matrix whose other entries are zeros, but in its diagonal and its last column are 5s

NOTE: Transpose of a matrix is obtained with command – '

- row with A(i,:) and column with A(:,j)

- Determine whether the given sets of vectors are linearly independent/dependent:

```
W1=[1 2 3], W2=[2 1 5], W3=[-1 2 -4], W4=[0 2 -1]
```

- Use MATLAB to to choose randomly three three column vectors in $\mathbb{R}^3$

  The MATLAB commands to choose these vectors are:

- `y1=rand(3,1)`
- `y2=rand(3,1)`
- `y3=rand(3,1)`

HINT check the command `rref`

2D GRAPHS

Main MATLAB functions for plotting graphs

Function	Meaning
`plot (x1, y1, x2, y2,…)`	Linear graphics
`stem`	Sequence graphs
`stairs`	Stairs graphs
`loglog`	Both Logarithmic axis Im and Re
`semilogx` `semiloxy`	Logarithmic Re axis Logarithmic Im axis

General rules of forming graphs

- `figure` – making a new window for a graph
- `subplot (n,m,p)` – drawing a few graphs in one window:

n – colum, m – row, p – ordinal number of the graph

- `hold on` – plotting another graph at the same picture
- `hold off`

- For more information `help graph2d`

Generate `x=[1 20 3 15 18];`

Use functions and tell what is the difference:

- `plot`
- `stem`

Generate `x1=0:pi/8:8*pi`. What we have done? Generate y(t)=sin(x). Use functions to plot graphs:

- `plot`
- `stem`
- `stairs`

- **HINT:** use command `figure` or function `subplot(n,m,p)`

Use `semilogx, semilogy, loglog` to plot graphs of the following functions:

1. y=3x^5
2. y=3^(5x-2)
3. y=log10(3x^4)

- Use subplot command into 3*3-subplot as described bellow

```
'case (1) semilogx'     'case (1) semilogy'     'case(1) loglog'
'case (2) semilogx'     'case (2) semilogy'     'case(2) loglog'
'case (3) semilogx'     'case (3) semilogy'     'case(3) loglog'
```

- Consider again `y=3x^5`. Use `plot(x,log10(y))` and compare its plot with semilogy plot. What is the difference and similarity between them?

Main tools of staging graphs

Function
`grid`
`title('<text>')`
`xlabel ('<text>')` `ylabel ('<text>')`
`Legend ('<funct1>','<funct2>',..,Pos)`
`axis([XMIN XMAX YMIN YMAX])`
`xlim ([XMIN XMAX])` `ylim ([YMIN YMAX])`

Pos (-1, 0, 1,…,4) TRY THEM!

Generate `x1=0:pi/8:8*pi; y1=sin(x1);`

Form 3 graph in 1 window.

- 1st graph: plot a discrete signal y(x)
- 2nd graph: plot a discrete signal. Use `axis([0 10 -1 1])`
- 3rd graph: do the same, but limit Re axis and Im axis by using `xlim([-15 15])` and `ylim([-1.5 1.5])`

For all graphs: make a grid, title and give names for both axis

Generate `y2=0.5*sin(2*x1);`

```
plot(x1,y1,x1,y2),legend('sin(x1)','0.5sin(2x1)');
```

!!!HINT: use `hold on`**!!!**

Controlling grpah properies

Each function has different properties.

- `plot(x1,y1,…,LineSpec,'PropertyName',PropertyValue,…);`
- `stem(x1,y1,…,LineSpec,'fill','MarkerSize',3);`

PropertyName is divided into:

- `LineWidth` – line width;
- `MarkerEdgeColor` – marker color ;
- `MarkerFaceColor` – color by which the marker is filled;
- `MarkerSize` – size of the marker , give a value (default - 7).

Let us divide `LineSpec` parameters into 3 groups: `s1, s2, s3.`

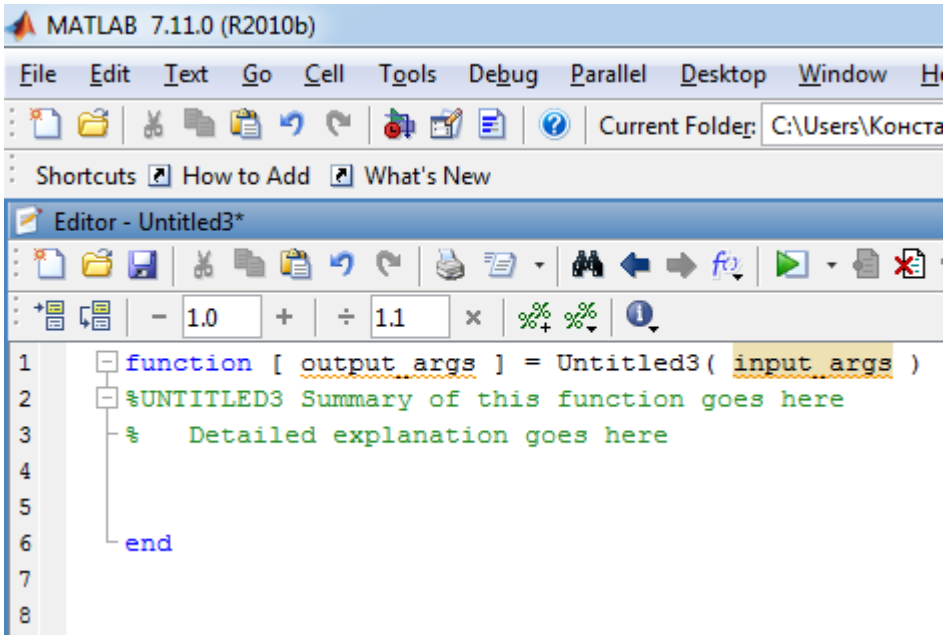
LineSpec parameters

S1		S2	S3	
r	Red	-	+	
b	Blue	:	*	
g	Green	-.	s	Square
w	White	--	d	Diamond
k	Black	(none)	v	
y	Yellow		^	
m	Magenta		<	
c	Cyan		>	
			p	Pentagram
			h	Hexagram

- Form a vector `y = [0 1 2 3 4 5 6 7 8 9];` line width is 2, use squared black markers, dotted line
- `x1=0:pi/8:8*pi; y1=sin(x1);` - line width 3, dashdot line, filled green markers, marker size 5
- `y1=sin(x1); y2=0.2*cos(5x1);` - one line is dashed, another is solid; one line is red, another is green; markers, different sizes

OUTER FUNCTIONS IN MATLAB

Function file – is a M-file, which generates outer function



DO NOT PUT ; after `function` row

After `function` there is a function body

Put ; everywhere in the body to prevent undesirable output

Good programming means good comments

- If you have a few parameters

```
function [z, p] = F1(x,y)
   % Sum of cubes z
   % Square root p
    z=x.^3+y.^3;
    p=sqrt(abs(z));
end
```

- If you have one parameter

```
function z = F2(x,y)
   % Sum of cubes z
    z=x.^3+y.^3;
end
```

- After making and saving function-file you can use it in other M-files (script files).
- Actual/Real parameters `a=4, b=3, [d,c]=F1(a,b)` => saved in Workspace
- Formal parameters `3+5-sqrt(9)` => not saved in Workspace

Number of input and output parameters can be formed by commands:

- `nargin('<function name>')`
- `nargout('<function name>')`

Listing of the function is formed by command:

- `type <name of function-file>`

If you need commends of the function file:

- `help <name of function-file>`

If you need to exit compulsory from the body of the outer function use operator:

- `return`

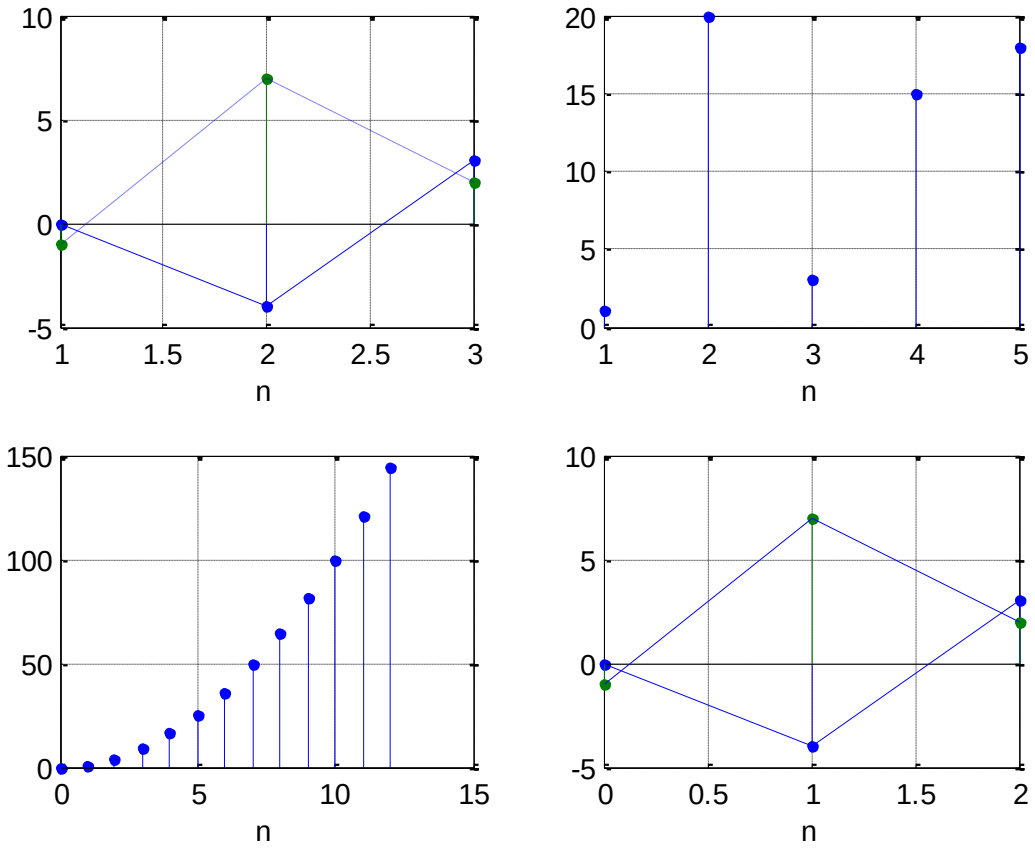
Let us remake function F1 to F3 with controlling negative argument of the square root and appropriation p=0 in this case:

```
function [z, p] = F3(x,y)
   % Sum of cubes z
   % Square root p
    z=x.^3+y.^3;
    if z<0
        p=0;
        return
   else
        p=sqrt(z);
   end
end
```

DESCRETE SIGNALS IN MATLAB

Sequences

- What is a discrete signal? How does it look like?
- How to make a discrete signal:
- Matrix `x=[0 -1; -4 7; 3 2];`
- Vector `y=[1 20 3 15 18];`
- Pair of vectors `n1=0:12; x1=n.^2;`
- Vector+Matrix `n2=0:2; x2=[0 -1; -4 7; 3 2];`


10
5
0
-5
1
1.5
2
2.5
3
n
20
15
10
5
0
1
2
3
4
5
n
150
100
50
0
0
5
10
15
n
10
5
0
-5
0
0.5
1
1.5
2
n

Unit sample sequence, unit step sequence, discrete exp,

Form a unit sample sequence, unit step sequence and discrete exp.

The length of the sequence is N=11. Plot graphs.

$$u_0(n) = \begin{cases} 1, n = 0; \\ 0, n \neq 0; \end{cases}$$

$$u_1(n) = \begin{cases} 1, n \geq 0; \\ 0, n < 0; \end{cases}$$

$$x(n) = \begin{cases} a^n, n \geq 0; \\ 0, n < 0; \end{cases}$$

Discrete complex harmonic signal

is presented as $x(n) = Ce^{j\omega Tn} = Ccos(\omega Tn) + jCsin(\omega Tn)$

or $x(n) = Ce^{j\hat{\omega}n} = Ccos(\hat{\omega}n) + jCsin(\hat{\omega}n)$, where $\hat{\omega} = \frac{\omega}{F_s} = \omega T$

Fs=1/T. Real and imaginary parts of x(n) are calculated

by functions `real` and `imag`. Absolute value and angle/phase can be

hound with the use of `abs` and `angle`

Now, present 32 samples of DCHS x(n), if C=2 and

w=pi/8. Plot real, imaginary parts of the signal.

Present absolute value and the phase of x(n).

Functions max, sum and prod

We can work only with vectors/matrices, which have the same length/dimentions.

Generate 3 signals `x1=(0.8.^n1)`, `x2=cos(w*n2)` and `x3=sin(w*n3)` with

vector length correspondingly `N1=16, N2=24, N3=32` and `w=pi/8`.

`N=max([N1 N2 N3])` – to find the maximum value of the vector length. To add the needed number of zeros to the signal:

`y1=[x1 zeros(1, (N-N1))];…`

Use `sum` to summate signals and `prod` to multiply signals. Check commands if needed in `help`.

Generation of signals: rectplus, triplus, gausplus, sinc, square, sawtooth, diric

There is a number of functions for generating signals in the folder

Signal Processing Toolbox.

```
y=rectpuls(t,w);

y=tripuls(t,w,s);

y=gauspuls(t,fc, bw);

y=sincpuls(t);

y=squarepuls(t,d);

y=sawtoothpuls(t,width);

y=diricpuls(x,N);
```

Functions rand(1, N) and randn(1, N)

`RAND` is a uniformly distributed pseudorandom number.

`RANDN` is a normally distributed pseudorandom numbers.

`(1, N)` – number of rows and columns.

Form additive mixture (sum) of sequence x(n)=sin(wn) with the length N=32 with white noise: uniformly distributed and normally distributed.

Thanks for attention!

Questions?