Session 1. Getting started with MATLAB/ Simulink

Lecture notes for Advanced modeling and Control

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Table 1: Useful functions

General functions:	
`help/ helpwin`	Help for functions in Command Window. Use `helpwin` for MATLAB file help displayed in a window
`cd`	Change current working directory.
`demo`	Launch the demo (introduction).
`dir/ what`	List folder. Use `what` to list MATLAB-specific files in directory.
`load`	Load data from MAT-file into workspace.
`lookfor`	Search for keyword in reference page text.
`print`	Print or save a figure or model.
`quit`	Quit MATLAB session.
`save`	Save workspace variables to file.
`who/ whos`	List current variables. Use `whos` for long form version of the list
Calculation functions:	
`conv`	Convolution and polynomial multiplication.
`size, length`	Size of an array, length of a vector
Plotting functions:	
`axis`	Control axis scaling and appearance.
`grid`	Add grid to plot
`hold`	Hold a figure to add more plots (curves)
`legend`	Add legend to plot
`plot`	Linear plot
`text (gtext)`	Add text (graphical control) to plot
`title`	Add title to plot
`xlabel, ylabel`	Add axis labels to plot
Partial fraction and transfer functions:	
`poly`	Construct a polynomial from its roots
`residue`	Partial-fraction expansion
`roots`	Find the roots to a polynomial
`tf2zp`	Transfer function to zero-pole form conversion

`zp2tf`	Zero-pole form to transfer function conversion
`tf`	Create a transfer function object
`get`	Listthe objectproperties
`pole`	Find the poles of a transfer function
`zpk`	Create a transfer function in pole-zero-gain form

Solution

The code demonstrating plotting functions is available in Matlab file/ mlx file.
The code demonstrating partial fractions and transfer functions is available in Matlab file/ mlx file.

Activities

1. Explore MATLAB user interface
2. Define a vector `x = [1 2 3 4 5 6 7 8 9 10]`.

   What are different ways you can define x? What happens when you put ; at the end?
3. Convert vector x into a column vector.
4. Create vector `y = [0, 0.1, 0.2, ...., 2.0]`
5. Create a 3 x 3 matrix.
6. Print the size of the matrix and lengths of vectors defined so far.
7. Define 3 polynomials

$$p_1(s) = s^2 - 5s + 4 \tag{1}$$

$$p_2(s) = s^2 + 4 \tag{2}$$

$$p_3(s) = s^2 - 5s \tag{3}$$

8. Calculate $p_1(s)p_2(s)$
9. Perform some mathematical computations on the vectors, matrices, and polynomials defined so far.

Solution

```
%% 2. Define a vector x in different ways
x1 = [1 2 3 4 5 6 7 8 9 10];      % explicit entry
x2 = 1:10;                        % using colon operator
x3 = linspace(1, 10, 10);         % using linspace
x = x1;                           % we'll use x1 as the main vector

% Semicolon at end suppresses output to console
% Without ;, MATLAB prints the result
x2                                % prints output
x3;                               % suppresses output

%% 3. Convert vector x into a column vector
x_col = x(:);

% Convert column vector to a row vector
% Transpose operator `'`
x_row = x_col';

% `reshape` function
x_row = reshape(x_col, 1, []);

%% 4. Create vector y = [0, 0.1, ..., 2.0]
y = 0:0.1:2.0;

%% 5. Create a 3 x 3 matrix
A = [1 2 3; 4 5 6; 7 8 9];

%% 6. Print size of matrix and lengths of vectors
disp('Size of matrix A:')
disp(size(A))

disp('Length of vector x:')
disp(length(x))

disp('Length of vector y:')
disp(length(y))

%% 7. Define 3 polynomials
% p1(s) = s^2 - 5s + 4
% p2(s) = s^2 + 0s + 4
% p3(s) = s^2 - 5s

p1 = [1 -5 4];
p2 = [1 0 4];
p3 = [1 -5 0];

%% 8. Calculate p1(s) * p2(s)
p12 = conv(p1, p2);

disp('Product polynomial p1 * p2:')
disp(p12)

%% 9. Perform some computations
```

10. Solve **Ax** = **b**

    `A = [ 4 -2 -10; 2 10 -12; -4 -6 16];`

    `b = [-10; 32; -16];`

11. Check the solution

12. Calculate eigenvalues and eigenvectors.

Solution

```
A = [ 4  -2 -10;
      2  10 -12;
     -4  -6  16];

b = [-10; 32; -16];

x = A \ b;

%% Compute eigenvalues and eigenvectors
[ev, l] = eig(A)

% ev is a matrix whose columns are the corresponding eigenvectors
% l is a diagonal matrix with eigenvalues of A on the diagonal

% verify : A*ev = l*ev

% If any eigenvalue has a positive real part, the system is unstable.
```

13. Consider data:

    `x = [ 0 1 2 4 6 10];`

    `y = [ 1 7 23 109 307 1231];`

    Fit a third-order polynomial. Plot the results

14. Explore MATLAB plotting capabilities

15. Create a MATLAB script, save, and load it to plot data in item 13.

Solution

Problem 13 - 15.

16. Find roots of polynomial defined by `p = [1 5 4]`

17. Search for a function to find roots of a nonlinear equation.

18. Find polynomial for the roots (-4, -1)

19. For the following transfer functions find partial fractions.

$$G(s) = \frac{q(s)}{p(s)} = \frac{2}{s^2+5s+4} \tag{4}$$

$$G(s) == \frac{2}{s(s+1)(s+2)(s+3)} \tag{5}$$

$$G(s) == \frac{s^3+4s+3}{s^4-7s^3+11s^2+7s-12} \tag{6}$$

Solution

```
% $$G(s) = \frac{q(s)}{p(s)}=\frac{2}{s^2+5s+4}$${#eq-4}
num = 2;
den = [1 5 4];

[r, p, k] = residue(num, den)

% $$G(s) = =\frac{2}{s (s + 1) (s + 2) (s + 3)}$${#eq-5}
num = 2;

factors = {[1 0], [1 1], [1 2], [1 3]};

den = factors{1};
for k = 2:length(factors)
    den = conv(den, factors{k});
end

[r, p, k] = residue(num, den)



% $$G(s) = =\frac{s^3 + 4s + 3}{s^4 - 7s^3 + 11s^2 + 7s -12}$${#eq-6}

num3 = [1 0 4 3];
den3 = [1 -7 11 7 -12];

[r, p, k] = residue(num, den)
```

20. Have fun with `zp2tf`, `tf2zp`, and `tf` commands
21. Response of first order system: Compute and plot step response of following first order systems

$$y(s) = \frac{1}{5s+1} \tag{7}$$

$$y(s) = \frac{5e^{-10s}}{2.5s+1} \tag{8}$$

Tip

```
%% First order system
% System 1: y(s) = 1 / (5s + 1)
num1 = 1;
den1 = [5 1];
sys1 = tf(num1, den1);

% System 2: y(s) = (5 * e^{-10s}) / (2.5s + 1)
num2 = 5;
den2 = [2.5 1];
delay = 10;  % Delay in seconds
sys2 = tf(5, [2.5 1], 'InputDelay', 10);

% Plot step responses
figure;
step(sys1, 'b', sys2, 'r--', 0:0.1:100);
legend('sys1', 'sys2');
xlabel('Time (s)');
ylabel('Response');
title('Step Response of First-Order Systems');
grid on;
```

22. Response of second order system: Compute and plot step response of following second order system. Show effect of ξ on response.

$$G_p(s) = \frac{Y(s)}{U(s)} = \frac{K_p e^{-\theta s}}{\tau^2 s^2 + 2\xi\tau s + 1} \tag{9}$$

$K_p = 1; \tau = 1; \theta = 10$

Solution

Problem 22.

23. Solve differential equations using Simulink

a) An object falling under gravity

$$\frac{d^2 y}{dt^2} = -g \tag{10}$$

Compare the result with analytical solution $y = -gt^2/2$

b) Systems of ODEs

1.

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 5y = 1 \tag{11}$$

$$\dot{y}(0) = y(0) = 0 \tag{12}$$

2.

$$\begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} + \begin{bmatrix} -2 & -5 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{13}$$

Solution

Problem 23.