# University of Ulsan
# School of Mechanical & Automotive Engineering

| Linear System Control | Spring 2019 |
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| Mid Term Exam | Date: 27/Apr |

<Attention>
- Submit your M-File only to the E-mail (kkahn@ulsan.ac.kr )
- File Name : LCS + your ID number(i.e.:20185096) + problem number(1 or 2 or 3).m (i.e. LCS201850961.m)
- Exam Time : 2019.04.27 PM1:30~PM5:30, Earlier submission has advantage.
  (~2:30 +50% Bonus, ~3:30 +20%, ~4:30 +10%, ~5:30 0%, Late than 5:30 0point)
- Open Book, But don't discuss with each other or get help from Lab. seniors.
- The M file is considered to be the same if the structure and variable names are almost the same.
  In that case, both of the records of exam become -50 points

Problem 1 Write a Matlab Program to plot a bode diagram with respect to the plant below.

In making the program, you **should NOT use bode function**, but you CAN use lsim, min, max, for, if and some math functions. The target frequency is as follows: (UNIT[rad/s])

w=[0.1 0.3 0.5 0.7 0.9 1.0 1.3 1.5 1.8 2.0 2.5 3.0 5.0 7.0 10]

$$G(s) = \frac{1}{s^2 + 0.3s + 1}$$

Problem 2 Write a Matlab Program to design a state feed back controller and simulate with respect to the following nonlinear system dynamics and initial conditions. (You must use nonlinear model for plant simulation and linear model for designing of state feedback controller)

$$\dddot{x} + 4\ddot{x} + (24 + 5\cos(x))|\dot{x}| + 50x = f$$

$$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} x \\ \dot{x} \\ \ddot{x} \end{bmatrix}, \quad X_0 = \begin{bmatrix} 0.05 \\ 0 \\ 0 \end{bmatrix}, f = 0$$

$$y = x$$

$$Desired\ Pole\ Position = [-3, -2+3i, -2-3i]$$

Problem 3 Parameter Identification Problem (No Time Delay and No disturbance)

Plant model was given as follows ( Ts=0.1ms)

$$y(k) = a_1 y(k-1) + a_2 y(k-2) + b_1 u(k-1) + b_2 u(k-2) + b_3 u(k-3)$$

Here u and y data set is given as data file(1st Column data is u and 2nd Column data is y. Each data was 0.1[s] interval).

First make a Matlab program to estimate the parameter a1, a2, b1, b2 and b3 using the algorithm of Recursive Least square(2nd page). Also plot the change of parameter a1, a2, b1, b2 and b3 with respect to time.

When loading the input, output data, use the following command

```
>> load inout.dat –ascii
```

# Recursive Least Square Algorithm

$$y(t) = a_1 y(t-1) + a_2 y(t-2) + \cdots + a_n y(t-n)$$

$$+ b_1 u(t-1-N) + b_2 u(t-2-N) + \cdots + b_r u(t-r-N)$$

## Recursive Least Squares Solution

$$y(t) = \Psi^T(t-1)\theta(t-1) + \varepsilon(t) \qquad (14)$$

where

$$\Psi^T(t-1) = [y(t-1), y(t-2), \ldots y(t-n), u(t-1-N), \ldots u(t-r-N)]$$

$$\theta^T(t-1) = [a_1,\ a_2, \ldots a_n,\ b_1,\ b_2,\ \ldots b_r\ ].$$

$$\min_{\hat{\theta}} \sum_{i=1}^{t} \underbrace{\left[\underline{\Psi}^T(i-1)\underline{\theta}(i) - y(i)\right]^2}_{\substack{\text{"least squares"} \\ \text{(predicted value of y)}}} \qquad (15)$$

$$\hat{\theta}(t) = \hat{\theta}(t-1) + P(t)\Psi(t-1)[y(t) - \Psi^T(t-1)\hat{\theta}(t-1)]$$

$$P(t) = P(t-1) - P(t-1)\psi(t-1)[\psi^T(t-1)P(t-1)\Psi(t-1) + 1]^{-1}$$

$$\Psi^T(t-1)P(t-1) \qquad (17)$$

$$K(t) = \frac{P(t-1)\Psi(t-1)}{1 + \Psi^T(t-1)P(t-1)\Psi(t-1)} \qquad (18)$$

$$P(t) = [I - K(t)\Psi^T(t-1)]P(t-1) \qquad (19)$$

$$\hat{\theta}(t) = \hat{\theta}(t-1) + K(t)[y(t) - \hat{y}(t)] \qquad (20)$$

$K$: Kalman filter gain