ECSE 403 lab assignment
Fall 2018 , assignment 4
Instructor: Prof. P. E. Caines
Due 26^{th} october 2018

Lab TA: Borna Sayedana

1 Objective

The main goal of this assignment is to design and implement P,PI,PD, and PID controllers for cart's position system.

2 Your responsibility

Your responsibility is to answer all questions which have been asked throughout this assignment and submit all your answers in addition to Matlab codes and Simulink results.

3 Questions

1. Derive the closed loop transfer function of a proportional position controller for the cart system(analytically).Identify ζ and ω_n from the closed loop transfer function and compute them for $K_p = [5, 10, 20, 50]$(Since you have derived a similar result in assignment 2, part 9 you can just plug in new coefficients)[10 marks]

2. Implement (experimentally) a proportional position controller in your Simulink model and plot the step response for $K_p = [5, 10, 20, 50]$. Explain as K_p increases, how do the rise time, overshoot, steady state error and damping change?[15 marks]

3. Tuning value of K_p, find an appropriate gain for proportional controller, i.e. change the value of K_p to get a step response with relatively low rise time while over shoot is relatively small.

Give the value of K_p and plot the step response. Report corresponding values for the rise time, maximum overshoot, settling time and steady state error from experimental results. [15 marks]

4. Compare the experimental step response with theoretical step response. Explain some of the reasons for the difference between the two step responses. [10 marks]

5. Estimate the frequency response of the closed loop system (position control) using $\omega = [1, 2, 5, 10, 20, 50]\frac{rad}{s}$ for $Kp = 10$ and $Kp = 50$ and plot the Bode diagram. [15 marks]

6. Plot both the Bode diagram you found in previous lab experimentally for the open-loop system(position as the output) and Bode diagram in question 5, on one figure. Explain the effect of a proportional feedback controller on frequency response. [5 marks]

7. Add a differentiating block and design a PD controller in the form of

$$C_{PD}(s) = K_p + K_d.s$$

   (a) Using a fixed K_p (K_p you found in question 3), increase the value of K_d gradually and explain the effect of adding a differentiating operator on step response of the system. Report the best K_d and plot step response of the system with PD controller along with best P controller(Question 3) on one figure. [10 marks]

   (b) Try to tune K_d and K_p, simultaneously. Report best combination of K_d and K_p you have found and plot the step response of the new PD controller. [10 marks]

8. Remove the differentiating block and replace it with an integrator to design a PI controller of the form

$$C_{PI}(s) = K_p + \frac{K_i}{s}$$

   (a) Using a fixed K_p (K_p you found in question 3), increase the value of K_i gradually and explain the effect of adding an integrator operator on step response of the system. Report the best K_i and plot step response of the system with PI controller along with best P controller(Question 3) on one figure. [10 marks]

   (b) Try to tune K_i and K_p, simultaneously. Report best combination of K_i and K_p you have found and plot the step response of the new PI controller. [10 marks]

9. Now add a differentiating block, to design a PID controller of the form

$$C_{PID}(s) = K_p + \frac{K_i}{s} + K_d.s$$

(a) Using values of K_d and K_p (in question 7), increase the value of K_i gradually and explain the effect of adding an integrator operator on step response of the system. Report the best K_i and plot step response of PID controller along with the best PD controller(Question 7) on one figure. [10 marks]

(b) Using values of K_i and K_p (in question 8), increase the value of K_d gradually and explain the effect of adding a differentiating operator on step response of the system. Report the best K_d and plot step response of PID controller along with the best PI controller(Question 8) on one figure. [10 marks]

(c) Try to tune all the three parameters K_p, K_i, K_d simultaneously to find a suitable step response.(report the parameters and plot the step response) [20 marks]

(d) By keeping two of the parameters fixed and increasing the third one, complete following chart. Write the effect of each of these controller gains on different parameters of the step response.[15 marks]

Table 1: PID controller

Gain	Rise Time	Overshoot	Settling time	Steady state error
K_p				
K_d				
K_i				