ME 417 - Num Assignment #2

Control of Mechanical Systems - Fall 2020

Num Assignment Due: Tue, 05 Jan 2021 23:59

Complete the following problems and submit your work as a working notebook and a saved pdf copy. *You can complete the numerical assignment using **Julia**, **Python** or **MATLAB**, and submit your work as a Jupyter Notebook (or MATLAB Livescript) + a pdf export*

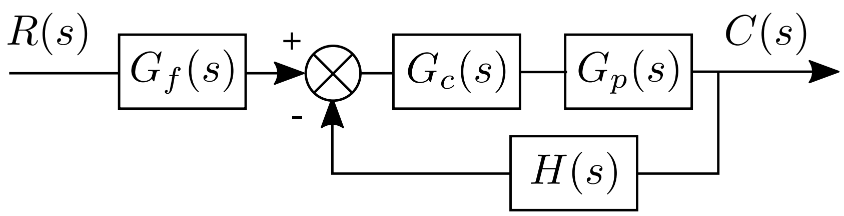
Provide response plots as relevant, ensure that you label the figures, the axes, title plots and legends. Any controller design specifications given, should be met by observing the time response of the system. The Numerical Lessons provided will aid greatly in carrying out this assignment.

Collaboration is only allowed within the group members.

Problem 1

Control of an unstable system (20pts)

Given the following transfer function



With

$$G_p(s) = \frac{100.0}{(s-3.0)\,(s-1.0)}, H(s) = 5, G_f(s) = 10$$

a. (50%) Using built-in commands of a control system package. Design a PID controller to achieve the following performance:

- $\%OS < 10\%$

- $T_s < 2.5s$

Plot the reference, input to the plant and output of the plant.

b. (25%) Test the closed-loop system, with the controller you designed against the following input.

$$r = \begin{cases} 0 & 0 < t \leq 0.1s \\ 1.5 & 0.1s < t \leq 0.2s \\ -1.5 & 0.2s < t \leq 0.4s \\ 0 & 0.4s < t \end{cases}$$

Plot the reference signal, input to the plant and output of the plant.

c. (25%) In a new plot representing the s-plane, place the poles and zeros of the open-loop system (without compensation), as well as the poles and zeros of the closed-loop system with the controller. Don't use rlocus(), but you can use package functions to retrieve pole and zero locations from a transfer function.

Problem 2

Parameter Identification (40pts)

You are given the response to a system in the form of logged data through a sensor, saved into a CSV file. You know that the sensor used, has the transfer fuction

$$H(s) = \frac{20.0s + 100.0}{s + 100.0}$$

a. (25%) Run the data through the inverted sensor transfer function to eliminate the affect of the sensor. Plot the logged data vs. the data with the sensor effect removed.

b. (50%) Identify, computationally, the parameters of the plant transfer function. If you are told that the system is a general second order system of the form

$$K\frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

c. (25%) Now that you have the plant transfer function, design a PID controller to achieve the following performance:

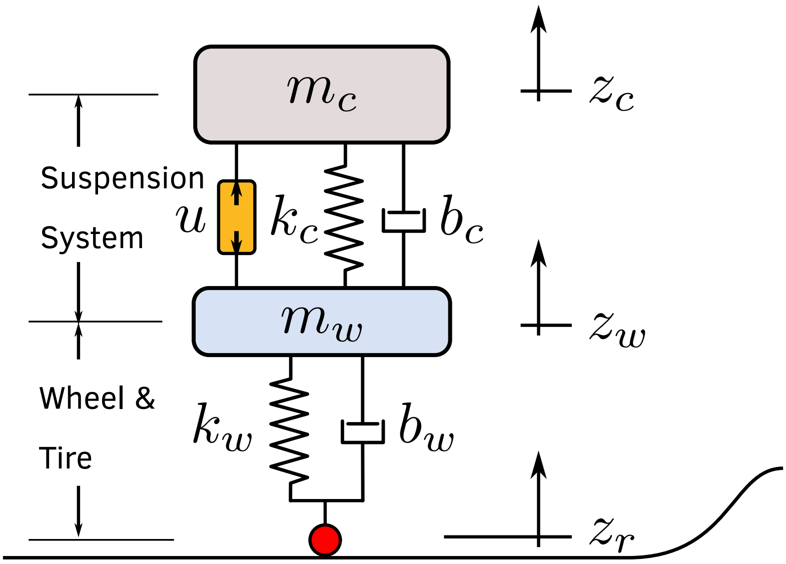
- $\zeta < .01$
- $T_s = 1s$
- Zero Steady-State Error

Plot the reference signal, input to the plant and output to the plant.

Problem 3

Multi-DOF Response to a Cyclic Input (40pts)

In the previous assignment, we modeled a passive quarter suspension model. Now we add a controller to make the suspesion system active. As shown.



With $m_c = 1.0$ Metric Tons, $m_w = 20kg, b_c = 1000N \cdot s/m, b_w = 900N \cdot s/m, k_c = 1500N/m, k_w = 2000N/m$

a. (20%) Derive the equations of motion for the system. Then derive, symbolically, the transfer function relating the actuator input to car height: $\frac{Z_c(s)}{U(s)}$.

b. (40%) Design a PID controller around the transfer function derived to achieve the following performance for a step input:

- $\zeta \leq 0.2$
- $\omega_d = \pi rad/s$

c. (40%) Simulate the PID controller in the basic numerical integration setup, where now the reference to your closed loop system is 0, you want to regulate the car height to go back to the equilibrium given changes in the road height. Simulate the response of your system with the controller for the following road level functions

- $z_r = 0.2sin(\pi vt)\,m$, for $v = 15km/h,\ 40km/h,\ 100km/h$

Where v is the speed of the car in m/s and t in seconds.

Plot the response of z_c to the three inputs in one subplot, and the three z_w responses in another.

Then plot the acceleration of both the car and wheel, $\ddot{z}_c$ and $\ddot{z}_w$ for the three z_r inputs