<u>Engineering 446</u>

Control Systems Laboratory

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Lab Assignment #3
The Effect of Controller Gain on open- and closed-loop responses

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Introduction

The fundamental goal of this laboratory assignment as to allow the user to get acquainted with a feel for the affect of the controller again on some vital system characteristics. It is important to be familiarized with systems not only in the time domain but also within the frequency domain. The specific plant being used in this laboratory assignment will be a third order system plant and the function is as follows:

:

$$G_p(s) = \frac{K_p {\omega_n}^2 (s+1)}{(\tau s + 1)(s^2 + 2\zeta\omega_n s + {\omega_n}^2)}$$

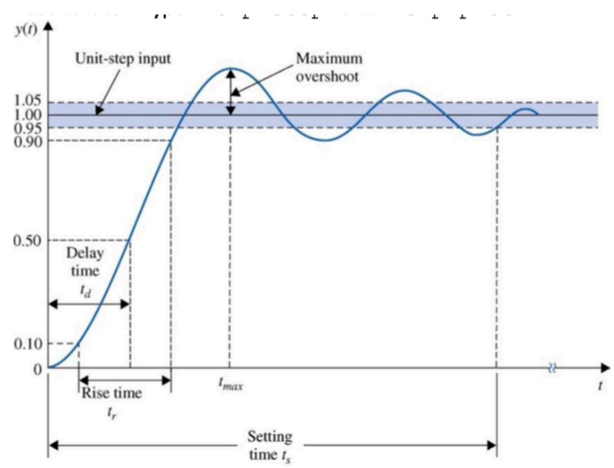
Specific values for the variables will vary throughout the lab. A real world example of this application would be the position control associated with a DC motor with time delay in the position sensor.

<u>Problem Definition</u>

The goal of this laboratory assignment is to plot the unit step responses of the open loops system for the range of controller gain values that are given; 0.2, 0.5, 1 and 10. The controller has a gain equivalent to, K_c, in the upstream direction of the plant in a system with no feedback or otherwise known as open loop. The loop around the system will then be closed with a unit negative feedback line in order to obtain the unit step response of the closed loop system for the range of controller games indicated previously. Matlab control system toolbox commands such as tf and step will be implemented instead of using Simulink. After the plots are generated for the given controller gains; the values of the following staff response characteristics of both the open and close loop systems of those simulated staff response data can be determined; a legend will be included to indicate these points.

Explanation of the experiments

The experimentation portion of this laboratory assignment requires the user to plot all the step responses of the controller game on the same plot, this is done to exploit the advantageous view of seeing all plots overlapped. In accordance to the sample code provided the numeric values of the end time and simulation resolution are modified in order to obtain a view that is more desirable to our objective. The Matlab code used in this project helps the user by retaining numerical values of critical information such as the steady-state air, rise time, Peak Time and peak overshoot and settling time. It is necessary for the experimenter to prepare a table that contains the observed values for the measured cases and these values should be reported directly from the plot using the data tip feature of Matlab.



The plot pictured above represents a typical plot of the function with the desired data points illustrated. Using Matlab, we can generate or find these points without doing any manual calculations by hand. Matlab makes finding the critical data of the staff response parameters plot very simple and straightforward. The user will experiment with the time interval to maximize the validity or usefulness of the plot.

Models/Calculations/ Simulation Results

Contained below is a table with the recorded, observed values from Matlab for the various cases of K_c:

	Step Response Kc = 0.2	Kc = 0.5	Kc = 1	Kc = 10
RiseTime	1.4277	1.4277	1.4277	1.4277
SettlingTime	1.8921	1.8921	1.8921	1.8921
SettlingMin	0.3490	0.8726	1.7451	17.4514
SettlingMax	0.3878	0.9695	1.9390	19.3900
Overshoot	0	0	0	0
Undershoot	0	0	0	0
Peak	0.3878	0.9695	1.9390	19.3900
PeakTime	2	2	2	2

	Step Response w/ feedback Kc = 0.2	Kc = 0.5	Kc = 1	Kc = 10
RiseTime	3.8164	2.6224	0.1671	0.0361
SettlingTime	7.4673	5.5310	4.1498	0.1887
SettlingMin	0.3375	0.5400	0.5188	0.5513
SettlingMax	0.3750	0.6000	0.7500	1.5001
Overshoot	0	0	0	55.014
Undershoot	0	0	0	0
Peak	0.3750	0.6000	0.7500	1.5001
PeakTime	20	20	20	0.0961

The plots generated are given below:

```
% Lab 3

s = tf('s')
Gp = 3 * 100 * (s + 1) / (3*s + 1) / (s^2 + 10*s + 100)
Kc = [0.2, 0.5, 1, 10]

figure(1)
hold
for n = 1:4
step(Kc(n) * Gp, 0:.0001:2)% Plot the step response; end time = 2 sec
legend('K_c = 0.2', 'K_c = 0.5', 'K_c = 1', 'K_c = 10')
    title('Step Response');
    xlabel('Time (secs)');
    ylabel('Amplitude');
[Y,T] = step(Kc(n) * Gp,0:.0001:2); % Simulation resolution is 0.0001 sec.
stepinfo(Y,T) % takes step response data (T,Y)
end
hold

    % Closed Loop
figure(2)
hold
for n = 1:4
step(feedback(Kc(n) * Gp, 1),0:.0001:1) % Plot the step response
    title('Step Response');
    xlabel('Time (secs)');
    ylabel('Amplitude');
legend('K_c = 0.2', 'K_c = 0.5', 'K_c = 1', 'K_c = 10')
[Y,T] = step(feedback(Kc(n) * Gp, 1),0:.0001:20);
                    % Generate data used by ?stepinfo? command
stepinfo(Y,T)
end
hold

% You may also explore settlingtime(Y,T,5); type h
```

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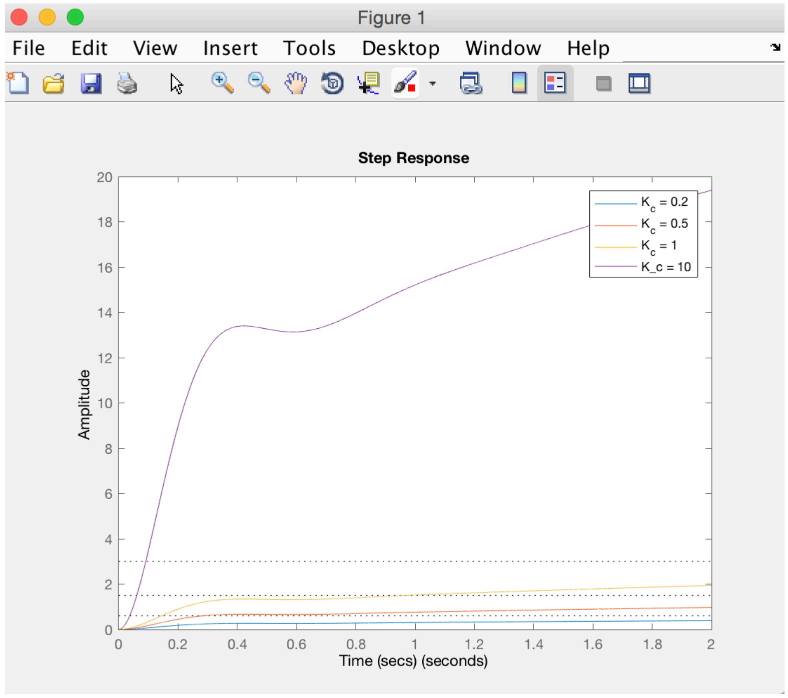
Figure 1
File Edit View Insert Tools Desktop Window Help
Step Response
Amplitude
Time (secs) (seconds)
K_c = 0.2
K_c = 0.5
K_c = 1
K_c = 10

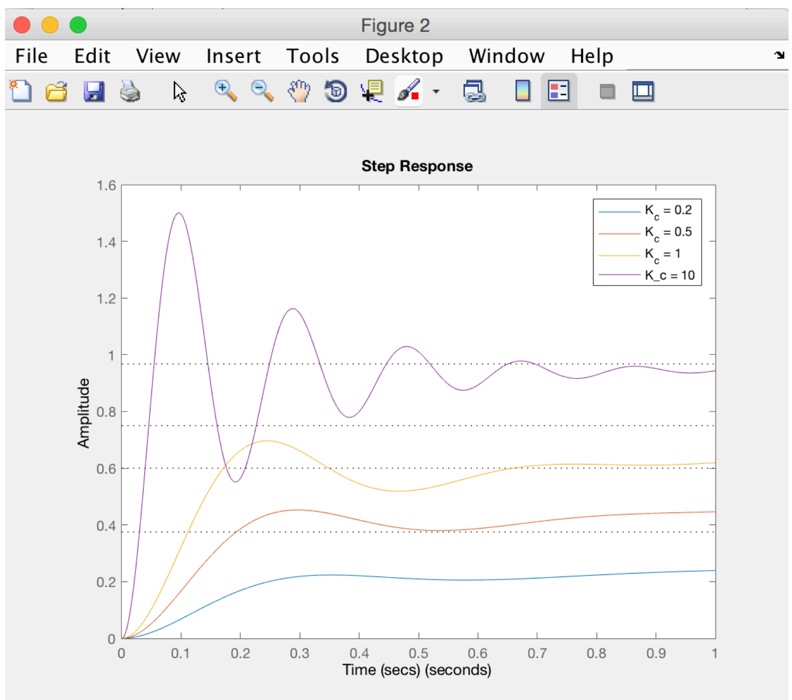
Figure 2
File Edit View Insert Tools Desktop Window Help
Step Response
Amplitude
Time (secs) (seconds)
K_c = 0.2
K_c = 0.5
K_c = 1
K_c = 10

Conclusions

When observing the effect of the controller game on the various critical system characteristics it is important to observe the system not only in time to Maine but also in frequency domain. The plant using the system was of the third order. In these systems the controller had a simple game and they forward upstream path of the plant, however two cases were absorbed and plotted. The case for the open loop system as well as the case for the closed loop system where feedback is applied. When plotting to step responses on the same plot the user can take in vantage of the overlapping plots to observe vital relationships. Matlab commands such as, stepinfo and Peak overshoot can also be used to acquire data. This was a good exercise and becoming acquainted with plotting the plant transfer function given the known values of the variables. Lots of critical information can be gathered from Matlab without making any manual calculations.

List of References

“Simulink Basics Tutorial”, SFSU 446 Laboratory manual book. Provided by University.