Lab 1: Introduction to MATLAB and Simulink

I. Objective

The goal of this lab is:

a. To help students become familiar with the MATLAB and Simulink environment.

b. Understand some of the basic concepts behind control theory: equilibrium points, stability, feedback, steady-state response, and linearization.

II. Theory

MATLAB (MATrix LABoratory) is an industry standard for control systems design. Simulink is the graphical front end to MATLAB.

Please note that Lab 1 assumes you are familiar with chapters 1 through 4 in your textbook.

III. Prelab

0. Documents

- Go to course website (http://www-inst.eecs.berkeley.edu/~ee128/fa10/labs.html) and download the lab documents.
- Become familiar with the "Transfer Functions" section of the MATLAB Commands document.
- Become familiar with the Simulink Components document (all but the QuaRC section).
- Read the Lab Policies document. **Print a copy and sign it. Bring this to lab.**
- Read the "Justin's Guide to Good Lab Writing" document and prepare your report.
- Prelab report should be done **individually** and is **due at the beginning of your assigned lab period at the week of 9/7**.
- Lab report can be done in group of **no more than 3 students** and is **due at the beginning of Lab2 period in your assigned lab section (the week of 9/14)**.

1. Simple feedback system

Consider the system shown in Figure 1 below.

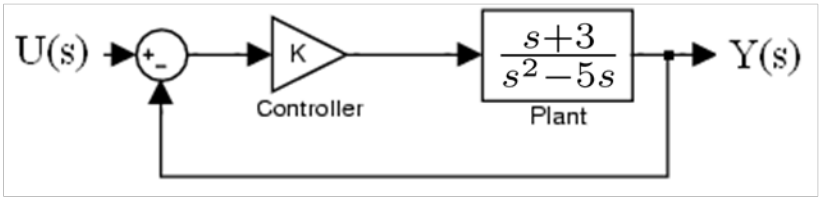

Figure 1: Simple proportional control system

Suppose the control goal is to track a step input.

a. What are the poles and zeros of the open-loop system? Is the open-loop system stable? Can the open-loop system track a step input? Explain.

b. Suppose you use proportional feedback control as shown in Figure 1. Explain *why* the scheme above is called proportional feedback. Explain *how* this scheme can be used to stabilize the system (show the *how* part mathematically).

c. Is the system stable for all values of K? Prove/disprove.

d. For what values of K is the system completely oscillatory?

e. For what values of K is the system stable?

2. Nonlinear damped pendulum

The dynamics of a real plant are often nonlinear in nature. There is a plethora of interesting mathematical and physical differences between linear and nonlinear systems. In this part, you study the mathematical differences between linear and nonlinear versions of the pendulum with respect to equilibrium points.

Consider the nonlinear equation of motion for a damped pendulum given by:

$$\ddot{\theta} + \frac{c}{ml}\dot{\theta} + \frac{g}{l}\sin(\theta) = \frac{T_c}{ml^2} \qquad (1)$$

Here θ is the angle of the pendulum from the vertical (in radians), c is the velocity damping term (in 1/s), m is the mass of the pendulum (in kilograms), l is the length (in meters),g is the acceleration due to gravity (in m/s^2) and T_c is the force input (in N). For this problem assume that $g = 9.81$, $l = 2$, $m = 1$, and $c = 0.1$.

a. What is the nonlinear term in the pendulum equation above?

b. Very often, you remove the nonlinearity in the plant by linearizing the plant about an operating point. In this case, we will do a Taylor series expansion for the nonlinearity and disregard the nonlinear terms in the expansion.

   What are the first three terms in the Taylor series expansion of the nonlinearity? What is the linearized version of the simple pendulum equation?

IV. Lab

0. General Instructions

The lab is located in 204 Cory Hall. Get a computer account from the TA. Log into any of the computers with your new EE128 student account and register.

1. Simple feedback system

a. **TASK 1:** Construct the simple feedback system shown in Figure 1 in Simulink. For the following tasks, plot the step input and the response of the system on the same graph:

b. **TASK 2:** Verify the system is oscillatory for all K values in the corresponding interval you found in the prelab.

c. **TASK 3:** Verify the system is stable for all K values in the corresponding interval you found in the prelab.

d. **TASK 4:** Suppose we want our output response to converge quickly to the final value of our input (step) signal. Let us specify that we want the maximum error at $t \geq t_0 + 5$ seconds, where t_0 is the start time of the step input, to be less than 0.05%. In this case, we define our tracking goal to be the output signal never exceeding a 0.05% bounds on either side of the input signal for all $t \geq t_0 + 5$.

USING SIMULATION (NOT MATH), determine for what values of K (find a range – precision of 0.1 for bounds is good enough) is the error 0.05% for $t \geq t_0 + 5$? Also show graphically that your bounds on K are correct (needs to be evident on plot).

Notice that in designing a control system we first analyzed the stability of our open-loop plant. If our open-loop plant is unstable, we use feedback to stabilize the system. Then we pick the values for the parameters in our control law so our control objective (in this case, a constraint on the settling time) is achieved. Of course, there will be other constraints (transient response for example). Satisfying all the design requirements is the goal of control theory.

2. Nonlinear damped pendulum

a. **TASK 5:** Design the nonlinear damped pendulum in Simulink. This is NOT a feedback system – you are building a block diagram representation of a plant! Instead of using derivatives, generate the necessary θ signals "backwards" by using integrators. Why might using numerical derivatives be bad? Make the model more robust by parameterizing the constants in your model.

b. **TASK 6:** Print the response (θ) of this system to a pulse having amplitude 10 and width 0.2 seconds. There are several ways to generate such a pulse; one easy way is to use a "pulse generator" with period = 100 and the appropriate pulse width. When you print the graph, show the response for 50 seconds of time. To what value is the pendulum angle converging to?

   (**Tip:** At some point you should also plot your pulse input to verify that it is the correct amplitude and width – this does not need to be included in your lab report, but will help you avoid mistakes)

c. **TASK 7:** Print the response (θ) of this system to a pulse having amplitude 250 and width 0.2 seconds. To what new value does the pendulum angle converge? Explain why.

d. **TASK 8:** Replace the nonlinear term in your Simulink model with the linear version. Repeat the experiment for the pulse with amplitude 10 and width 0.2 seconds. Do the nonlinear and linear versions agree for the angle response?

e. **TASK 9:** Now try the linear version with the pulse having amplitude 250 and width 0.2 seconds. Do the nonlinear and linear versions agree for the angle response? Why is there a discrepancy?

f. **TASK 10:** Based on your results from tasks 8 and 9, is the linear approximation a "good" approximation?

V. Revision History

Semester and Revision	Author(s)	Comments
Fall 2010 Rev. 2.2	Wenjie Chen, Jansen Sheng	Modified some questions and solutions from Fall 2009 lab
Fall 2009 Rev. 2.1	Justin Hsia	Rewrote questions for better clarity following Fall 2009 lab
Winter 2008 Rev. 2.0	Justin Hsia	1. Segmented lab into separate documents: MATLAB, Simulink, Lab Policies. 2. Reformatted lab in Word 2007.

Fall 2008 Rev. 1.1	Justin Hsia	Changed lab policies regarding group size and write-up
Summer 2008 Rev. 1.0	Bharathwaj Muthuswamy	1. Formatted writeup into different sections 2. Typed up solutions
Fall 2005 Rev. 0.0	Ping Hsu	Initial version of the lab writeup