Lab 8: State Variable Control and Regulator Systems

Overview

In this lab you will be controlling your two one degree of freedom systems you previously modeled using state controllers. You will also learn what a regulator system is.

You will need your model files for each system, ***Basic_1dof_State_Variable_Model.mdl,*** *and* ***Basic_1dof_State_Variable_Model_Driver.m*** *for this lab.*

Design Specifications: *For each of your systems, you should try and adjust your parameters until you have achieved the following:*

Torsional Systems (Model 205)

- Settling time less than 0.5 seconds.
- Steady state error less than 2 degrees for a 15 degree step, and less than 1 degree for a 10 degree step (*the input to the Model 205 must be in radians!*)
- Percent Overshoot less than 10%

Rectilinear Systems (Model 210)

- Settling time less than 0.5 seconds.
- Steady state error less than 0.1 cm for a 1 cm step, and less than 0.05 cm for a 0.5 cm step
- Percent Overshoot less than 10%

Your memo should include plots of the response of the real system and of the model for each of your 1 dof systems. Specifically, you need to plot the position of both the real system and the position of the model on one graph, and the velocity of both the real system and the velocity of the model on one graph. Use subplot to put them both on the same page and be sure to use a legend command and different line styles so I can tell them apart. Don't depend on colors unless you print them on a color printer.
You should have plots for for pole placement and for the LQR design for each of your systems. Be sure to include the values of the closed loop poles and the gains for the LQR algorithm in the caption for each figure. Your memo should compare the difference between the predicted response (from the model) and the real response (from the real system) for each of the systems. You should also have a picture of the position of the cart (or disk) when the system is used as a regulator system (with disturbances).

Part A: State Variable Control

For each of your two 1 dof systems, you will need to go through the following steps:

Step 1: Set up the 1 dof system exactly the way it was when you determined its model parameters.

Step 2: Modify **Basic_1dof_State_Variable_Model_Driver.m** to read in the correct model file and to use the correct *saturation_level* for the system you are using.

Step 4: Pole Placement Design

- Design a state variable controller using pole placement to control the position of the cart or disk and meet the design specs (you may have already done this in the homework). Use a **constant prefilter**.

- Simulate the system for 1.5 seconds. *Be sure to use radians for the Model 205 system!* If the design constrains are not met, or the control effort hits a limit, redesign your controller (you might also try a lower input signal)

- Compile the correct closed loop ECP Simulink driver, connect to the system, and run the simulation. For the model 205 this is **Model205_sv1.mdl** while for the model 210 use the file **Model210_sv1.mdl**.

- Use the **compare1.m** file (or a modification of it) to plot the results of both the simulation and the real system on two nice, neatly labeled graphs. **You need to compare both the position and the velocity of the cart/disk.** The results for the torsional systems must be displayed in degrees and degrees/sec. You need to include these graphs in your memo. *(Note: the steady state error is likely to be off. Placing the poles farther away can reduce this error for these systems.)*

Step 5: LQR Design

- Design a state variable controller using the LQR algorithm to control the position of the cart or disk and meet the design specs (you may have already done this in the homework). Use a **constant prefilter**.

- Simulate the system for 1.5 seconds. *Be sure to use radians for the Model 205 system!* If the design constrains are not met, or the control effort hits a limit, redesign your controller (you might also try a lower input signal)

- Compile the correct closed loop ECP Simulink driver, connect to the system, and run the simulation. For the model 205 this **is Model205_sv1.mdl** while for the model 210 use the file **Model210_sv1.mdl**.

- Use the **compare1.m** file (or a modification of it) to plot the results of both the simulation and the real system on two nice, neatly labeled graphs. **You need to compare both the position and the velocity of the cart/disk.** The results for the torsional systems must be displayed in degrees and degrees/sec. You need to include these graphs in your memo.

Part B: State Variable Control for a Regulator System

While for a *control system* we are generally trying to have the output follow the input (i.e. you put in a 1 cm reference input and you want the cart to move 1 cm), for a *regulator system* we want the system to stay in one place. For example, your home or apartment heating system is usually used as a regulator system since we want the temperature to remain at a constant value. Often one system functions as both a control system (to get where we want the output to go), and then as a regulator system (to keep it there when there are external disturbances).

Step 1: *Set up the original 1 dof system*

- Set up the system in one of your configurations. Be sure there are masses on the cart (or disk).

- Simulate the system as before to be sure the feedback gains are acceptable.

- Implement the system on the ECP system to be sure it is working as before.

Step 2: *Prepare for the regulator system*

For the model 210 systems, unlock the stops so the second cart can move. Remove any springs between the second cart and the third cart. For the model 205 systems, be sure the second disk is free to move (is unlocked) and the top disk is unlocked and free to move. You will need to have two masses symmetrically located on the second disk of the model 205 system.

Step 3: *Determine the set point and the length of time to run the system*

- Set the amplitude (Amp) to zero. You should do this in the Matlab workspace. Hence we want to keep the cart (or disk) at zero. This is the ***setpoint***.

- Set the length of time to run the system (Tf) to 20 seconds. You should do this in the Matlab workspace

- Reset your system using **ECPDSPReset.mdl**

- Recompile the ECP Driver for your system. (**Model205_sv1.mdl** or **Model210_sv1.mdl**)

- Run the system. Nothing should happen. After a short time, *<u>using the ruler</u>* you have been given (do not directly touch the systems), ***<u>gently</u>*** push on the second cart (either toward the first cart or away, or both) and then let it go. For the torisional systems, *<u>use the ruler</u>* to ***<u>gently</u>*** push on the second disk and then let it go. You should see your system return to 0 (or very close to it).

- Plot the position of the first cart (or disk) as a function of time. Be sure it is nicely labeled and has a grid on it. Your plot should show your displacement (or hopefully, multiple displacements) and then the regulator moving the system back to the set point.