Lab 9: State Variable Control

Overview

In this lab you will be controlling the one and two degree of freedom systems you previously modeled using state controllers.

If you modeled two rectilinear 1 dof systems, start with the rectilinear systems. If you modeled two torsional 1 dof systems, start with the torsional systems.

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 four graphs for each of the 1 dof systems you used (two (position and velocity) for pole placement and two (position and velocity) for the LQR design.) You should also have 16 graphs for the 2 dof system (2 position and 2 velocity for each algorithm, two carts/disks.) 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.

For each of your three 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 of 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 position 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 of 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.

For your two dof system, you will need to first go through the following steps:

Step 1: Set up the 2 dof system exactly the way it was when you determined its model parameters.

Step 2: Copy **Basic_1dof_State_Variable_Model_Driver.m** to **Basic_2dof_State_Variable_Model_Driver.m** and **Basic_1dof_State_Variable_Model.mdl** to **Basic_2dof_State_Variable_Model.mdl**.

Step 3: Modify **Basic_2dof_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: Modify **Basic_2dof_State_Variable_Model_Driver.m** to get all four states. To do this, modify the top of the code to read

```
get_desired_states = [1 0 0 0 0 0 0 0;
                      0 1 0 0 0 0 0 0;
                      0 0 1 0 0 0 0 0;
                      0 0 0 1 0 0 0 0];
```

Step 5: Modify **Basic_2dof_State_Variable_Model.mdl** so there are 4 initial states for the integrator, like [ic_x1; ic_x1_dot; ic_x2; ic_x2_dot] and then modify **Basic_2dof_State_Model_Driver.m** to set these initial states to zero.

Step 6: Modify **Basic_2dof_State_Variable_Model.mdl** to write four states to the workspace. The output states should be (from top to bottom) m_x1, m_x1_dot, m_x2, m_x2_dot.

Step 7: Modify **Basic_2dof_State_Variable_Model_Driver.m** to plot all four states (neatly labeled), the control effort, and both the input and the output on one graph. There should be 6 graphs on one page.

Step 8: Copy **Model210_sv1.mdl** to **Model210_sv2.mdl** (or **Model205_sv1.mdl** to **Model205_sv2.mdl)** and modify them to write four states to the workspace. The output states should be (from top to bottom) x1, x1_dot, x2, x2_dot.

The C matrix determines which cart/disk we are trying to control the position of. To control the position of the second cart/disk, set C = [0 0 1 0] just after the state variable model is read into the system. To control the position of the first cart, set C = [1 0 0 0] just after the state variable model is read into the system. You need to use both pole placement and the LQR algorithm to try and control the position of both the first and second carts/disks.

<u>Step 9:</u> Pole Placement Design

- Design a state variable controller using pole placement to control the position of the cart of disk and meet the design specs. 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.

- Use the **compare1.m** file (or a modification of it) to plot the results of both the simulation and the real system on four nice, neatly labeled graphs. **<u>You need to plot both the position and velocity of both carts/disks.</u>** 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 position error is likely to be off. Placing the poles farther away can reduce this error for these systems.)*

<u>Step 10:</u> LQR Design

- Design a state variable controller using the LQR algorithm to control the position of the cart of 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.

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