ECE-520 Lab 8

Minimum Order Observers with State Variable Feedback and Integral Control For One and Two Degree of Freedom Systems

Overview

For each of the systems you use in this lab you will go through the following basic procedure:

1) *You should choose a sampling rate that works well. A good start would be to use the sampling rates you used in the last lab. The sampling rate can be different for each system.*
2) *Simulate the system to determine if your model meets the desired specifications. If it does not, modify the pole locations until it does meet the specifications. In addition, you need to be sure the control effort does not reach the saturation level. The simulated control effort for the discrete-time system does not model the real control effort as well as it does for the continuous time system.*
3) *Once you have simulated the system all of the variables you used are in Matlab's workspace. Now compile the correct ECP driver file that replaces the model of the ECP system with the ECP system driver (and the real ECP system). Reset the ECP system, and run the system.*
4) *Finally, compare the estimated states with the actual states. A graph showing the estimated and real states is to be included in your memo (as an attachment) for each system you simulate. Even if you assumed a state was known in the minimum observer, plot the estimated and true states.*

If you are working along, you need to use both 1dof systems and only one 2dof system.

Notes and Guidlines:

- Although it should not matter, only use *positive* pole locations. Apparently the ECP systems are not particularly happy with negative pole locations.

- We are going to have to have to poles fairly close to the origin for our systems to work. However, as the sampling rate increases, we will have to move the state feedback poles farther away. The observer poles should generally be closer in than the state feedback poles.

- The ECP systems really do not like poles at the origin, so don't put any state feedback poles there (no deadbeat control.) However, for many of your systems you should be able to put the observer poles there.

- Run the systems for at least one second, but don't run the system so long most of your graph shows the system at steady state.

- Reset the system each time before you run it.

- As soon as you start you controller (click on play) be prepared to stop the system. In particular, listen for vibrations that are growing louder and stop the system as soon as possible after this.

Design Specifications

For each of your systems try and have the simulated systems meet the following design specifications

a) Settling time less than or equal to one second
b) Steady state error is zero for a 1 cm step input (or a 15 degree step input)
c) Percent overshoot less than 20%

You should try for the 1cm (or 15 degree) inputs, but if your system is unwilling to cooperate try a 0.5 cm input (or a 10 degree input). This is particularly true when trying to control the position of the second cart/disk.

Note that the error in the observers will really only go to zero if the model exactly matches the real plant. This is not the case for us, so you can expect the estimated states to differ from the real states, particularly the states which are velocities.

Part A1: One Degree of Freedom Rectiliner Systems without Integral Control

a) Use a minimum order observer to estimates the states coupled with state variable feedback in such a way that you think you will meet the system requirements given above. Assume the position of the system is known. You should assume the states are in the order $\begin{bmatrix} x & \dot{x} & u_d \end{bmatrix}$ and leave them in this. ***Hence you do not need to rearrange the order of the states!*** Be sure your demuxes are correct (they are different than they were for the homework!) Look at last week's results to determine where to initially try to place your poles and an acceptable sampling rate. Set all initial conditions in your simulation to zero.
b) Run the simulation for at least one second (*Tf should be at least one second*). This is because the ECP systems tend to hang up if they run for less than a second.
c) Simulate the system, check to see that they meet the design requirements and the control effort does not reach the saturation level. If there is a problem try a different set of pole locations.
d) Reset the ECP system.
e) Connect **Model210_DT_sv1_min_observer.mdl** to the ECP system and run it.
f) Plot the measured and estimated states on the same graph. Do not plot the third state since it is not really all that important.
g) Copy and paste this graph into your **Word** document that will eventually become your memo for this lab. It is a real good idea to write a short caption at this time so you don't forget what you just did. Be sure to include the (observer and state feedback) pole locations in the caption. In addition, include the sampling interval.

Part A2: One Degree of Freedom Rectiliner Systems with Integral Control

For this part do the same thing you did in part **A1**, except utilize integral control. Be sure to include the (observer and state feedback) pole locations, and the sampling interval, in the caption.

Part B1: Two Degree of Freedom Rectiliner Systems without Integral Control

For this system you need to basically go through the same steps you used in **PART A1** However, you need to assume the states are in the order $\begin{bmatrix} x_2 & x_1 & \dot{x}_1 & \dot{x}_2 & u_d \end{bmatrix}^T$ and change the **get_desired_states** variable as follows:

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

Try to run the following two cases

a) the observer has available the position of the second cart and we are trying to control the position of the second cart
b) the observer has available the position of both the first and second cart and we are trying to control the position of the second cart. You will likely need a higher sampling rate (smaller sampling interval) for this one. Some of you may not be able to get this to go, but you should try.

You should compare the estimated states with the real states for each of the two cases. Be sure to include the (observer and state feedback) pole location sand the sampling interval in the captions.

Part B2: Two Degree of Freedom Rectiliner Systems with Integral Control

Similar to **B1**, but include the use of integral control.

Part C1: One Degree of Freedom Torsional Systems without Integral Control

For this system you need to basically go through the same steps you used in **PART A1**, except you will need to use the one degree of freedom torsional system.

Even though I indicated the desired input in degrees, your mathematical model (and the ECP system) works in radians, so ***your input must be in radians.***

Be sure to include a plot comparing the true and estimated states and include the pole locations. It should also indicate the sampling interval. ***You should plot your outputs in degrees or degrees/second***

Part C2: One Degree of Freedom Torsional Systems with Integral Control

Same as **C1**, but include integral control.

Part D1: Two Degree of Freedom Torsional Systems without Integral Control

For this system you need to basically go through the same steps you used in part **B1,** using the two degree of freedom torsional system. You again need to assume the states are in the order $\begin{bmatrix} x_2 & x_1 & \dot{x}_1 & \dot{x}_2 & u_d \end{bmatrix}^T$ and change the **get_desired_states** variable as follows:

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

Even though I indicated the desired input in degrees, your mathematical model (and the ECP system) works in radians, so ***your input must be in radians.***

Be sure to include a plot comparing the true and estimated states and include the pole locations, as well as the sampling interval. ***You should plot your outputs in degrees or degrees/second***

Part D2: Two Degree of Freedom Torsional Systems with Integral Control

Same as **D1**, but include integral control.

Even though I indicated the desired input in degrees, your mathematical model (and the ECP system) works in radians, so ***your input must be in radians.***

Be sure to include a plot comparing the true and estimated states and include the pole locations, as well as the sampling intervals. ***You should plot your outputs in degrees or degrees/second***

Your memo should summarize how well the estimators predicted the true states of the systems, and whether including the integrator improved on the steady state error (compared to not having an integrator in the system).

*You should have a whole bunch of plots (**A1**-1, **A2**-1, **B1**-2, **B2**-2, **C1**-1, **C2**-1, **D1**-2, **D2**-2) and each caption should indicate the position of the state feedback and observer poles, as well as the sampling interval.*

Rather than printing your memo out, you can send me an electronic version.