ECE-520 Lab 7

Full Order (Prediction) Observers with State Variable Feedback and Integral Control For One and Two Degree of Freedom Systems

Overview

In this lab you will be utilizing full order (prediction) observers with state variable feedback control to place the poles in a closed loop system to improve the performance of your open loop one and two degree of freedom systems. In addition, you will be incorporating integral control to try and produce zero steady state error for a step input.

For each of the systems you use in this lab (and for the remainder of the labs in this course) you will go through the following basic procedure:

1) *Modify the Simulink driver you are using to load the mathematical model file (.mat file) that corresponds to the way you have the system configured.*
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. It would work better if we were to sample at a higher rate. Hence, if your control effort is near the saturation level it is not likely to work well.*
3) *You may reduce the sampling interval if necessary to achieve better results, but this often leads to increased control effort.*
4) *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.*
5) *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.*

If there is only one person in the "group" you only need to do one 2-degree of freedom systems. Hopefully this will be the system that works the best.

Notes and Guidlines:

- Although it should not matter, only use *positive* pole locations. Apparently the ECP system 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. The observer poles should generally be closer in than the state feedback poles. If your system does not seem to work well, try placing the poles closer to the origin.

- 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 your 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.

- Start with a sampling interval of 0.05 seconds and decrease this as necessary to get good results.

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) Load the files from the **Lab 6** folder into a folder for **Lab 7**.
b) Configure your one degree of freedom system the way you did in **Lab 1**.
c) Modify the Matlab driver file **DT_sv1_observer_driver.m** to read in the appropriate mathematical model.
d) Assume the position of the cart is available to the observer, and we are also trying to control the position of the cart.
e) Use a full order (prediction) 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. I put all my state feedback poles all at 0.3 and the observer poles all at either 0.1 or 0 (deadbeat response). This may not work for your system, but you might want to start with these.
f) *Set all initial conditions in both your simulation to zero*.
g) 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.
h) Simulate the system, check to see that they meet the design requirements and the control effort does not reach the saturatation level. If there is a problem, go to step (e) and try a different set of pole locations.
i) Create the file **Model210_DT_sv1_observer.mdl** to implement the observer and controller. Be sure your write out (save to the workspace) both the real states and the estimated states.
j) Reset the ECP system.
k) Connect **Model210_DT_sv1_observer.mdl** to the ECP system and run it.
l) Copy the program **Compare_DT1.m** to **Compare_obs_DT1.m** and modify this new program to produce a plot comparing the estimated states with the true states (like you did on your homework). Each measured state and its estimate should be on the same plot. Note that the third state is not plotted since it is not really all that important.
m) 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 and the sampling interval Ts in the caption.

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 both state feedback and integral control. You will want to utilize your program **DT_sv1_obs_servo_driver.m.** You will need to create a file **Model210_DT_sv1_obs_servo.mdl** to run the ECP system. You should start off placing your poles where you did for part **A1**, but you may have to move them even closer. Copy your final plot comparing the true and estimated states into your memo. Be sure to include the (observer and state feedback) pole locations and the sampling interval Ts in the caption.

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

For this system you need to go through the same steps you used in **PART A1**, except you will need to use the programs **DT_sv2_observer.mdl** and **DT_sv2_observer_driver.m** you wrote for your homework. You will also need to create the Simulink file **Model210_DT_sv2_observer.mdl**

Configure your two degree of freedom system the way you did in **Lab 2** and load the appropriate mathematical model.

For my system I put the state feedback poles all at 0.2 and the observer poles at 0.06, 0.08, 0.10, 0.12, and 0.14.

Copy the program **Compare_DT2.m** to **Compare_obs_DT2.m** and modify this new program to produce a plot comparing the estimated states with the true states (like you did on your homework). Each measured state and its estimate should be on the same plot. Note that the fifth state is not plotted since it is not really all that important.

Assume the observer has available the position of the second cart. If this does not work very well assume it has available the positions of both carts. We are trying to control the position of the first cart, and then we are trying to control the position of the second cart. (Two separate cases.) 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 locations in the caption.

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

Similar to **B1**, but include the use of integral control. Be sure to include both plots in your memo. You will need to use **DT_sv2_obs_servo_driver.m** you wrote for your homework. You will also need to create the Simulink file **Model210_DT_sv2_obs_servo.mdl**

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 modify the program **DT_sv1_observer_driver.m** to work with a the model you created for the one degree of freedom torsional system that seemed to work best.

Configure your one degree of freedom system the way you did in **Lab 1**.

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.***

You will need to create program the **Model205_DT_sv1_observer.mdl** to interface with the torsional system**.**

Be sure to include a plot comparing the true and estimated states and include the pole locations. ***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. You will need to use the program **DT_sv1_obs_servo_drive**r.m you wrote for your homework, and you will need to create **Model205_DT_sv1_obs_servo.mdl** to interface with the torsional system**.**

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**, except you will need to use **DT_sv2_observer_driver.m** you wrote for your homework.

You will need to create **Model205_DT_sv2_observer.mdl.** Determine which of the models you created for the two degree of freedom torsional system seemed to work best last week and use that model.

Configure your two degree of freedom system the way you did in **Lab 2** and read in the appropriate mathematical model.

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. ***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. You will need to use the program **DT_sv2_obs_servo_drive**r.m you wrote for your homework, and you will need to create **Model205_DT_sv2_obs_servo.mdl** to interface with the torsional system**.**

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). Was it easier to estimate the positions or the velocities?

*If you use both 2 dof systems you should have 12 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.*

If there is only one person in the "group" you only need to do one 2-degree of freedom systems. Hopefully this will be the system that works the best.