# <u>ECE-521</u>

## *Lab 7: Reduced Order Observers and Type One State Variable Feedback Systems*

*Note: Be sure all initial estimates in your observers are set to zero before you try and control the ECP system.*

***<u>One degree of freedom system.</u>***

a) Set up the one degree of freedom system you used in lab 1.

b) Try and control the system with a controller you used in lab 1 and be sure you get similar results. (This is just a starting point to be sure the system is behaving in the same manner as before.)

c) Simulate the system with a state feedback controller and a reduced order observer, assuming the position of the cart is known but not the velocity. Place the closed loop poles near -15 and -20 and the reduced order observer pole at **p** = -20. If your system does not seem to work you may need to put the observer poles at 2**p** or 4**p** to start with.

d) Run the ECP system with your controller/reduced order observer.

e) Compare the actual states (from the ECP system), the predicted states (from the model), and the estimated states (from the observer implemented in the ECP system). You will have to modify compare1.m to do this. Be sure to change the legend command and use different line types so the results will be acceptable with black and white printers. Only plot until the system reaches steady state. Your system may have a position error, but we'll fix that later.

f) Make a plot of the estimated state versus time. (Only the estimated state!)

g) Repeat steps (c-f) keeping the state variable poles where they are but changing the observer poles to **4p** and **8p**. (If you started with the poles at 2**p** or 4**p**, move them even farther away, like 6**p** or 8**p** or 10**p.** Try for two more locations**.**) You should notice two things: (1) as the observer poles become more negative, the observer estimated states converge more quickly to the true states, and (2) as the observer poles become more negative the estimated states are not very smooth. This is because we are now letting more noise into the system (by increasing the observer's bandwidth). Be aware that our ``true'' derivative is really just an estimate itself. You may also notice that the position is closer to what the model predicts as the observer poles move away from the imaginary axis.

h) Simulate the system with a state feedback controller and a reduced order observer, with a configuration that forces a type 1 system. Try to place the closed loop poles near -20, -25 and -30. Do not try for a particularly fast response, it will overwhelm the system! Again assume the observer pole is at **p** = -20, or wherever you placed the pole for part c.

i) Run the ECP system with your controller/reduced order observer type 1 system configuration.

j) Compare the actual states (from the ECP system), the predicted states (from the model), and the estimated states (from the observer implemented in the ECP system). Only plot until the system reaches steady state. Your system should have near zero position error.

k) Repeat steps (h,i,j) keeping the state variable poles where they are but changing the observer poles to **4p** and **8p** (or where ever you move them to in part g). This system is really driven by its desire to produce zero position error. Most likely you will notice that the observer estimated velocity for this type 1 system is much worse than for the original system with just an observer.

***<u>Two degree of freedom system.</u>***

*Be sure to modify the* ***<u>get_desired_states</u>*** *array before you run the ECP system. Your state variables must be in the correct order!*

a) Set up the two degree of freedom system you used in lab 2.

b) Try and control the system with a controller you used in lab 2 and be sure you get similar results. (This is just a starting point to be sure the system is behaving in the same manner as before)

c) Simulate the system with a state feedback controller and a reduced order observer. Assume the ***<u>positions of both carts are known</u>*** but the velocities are not and we are trying to ***<u>control the position of the first cart</u>***. Place the closed loop poles near -10 -15, -20, and -25 and the observer poles at **p** = [-20 -25]. Do not try for a particularly fast response, it will overwhelm the system! If your system does not seem to work well you may need to place the observer poles at 2**p** or 4**p** to start with.

d) Run the ECP system with your controller/reduced order observer.

e) Compare the actual states (from the ECP system), the predicted states (from the model), and the estimated states (from the observer implemented in the ECP system). You will have to modify compare2.m to do this. Be sure to change the legend command and use different line types so the results will be acceptable with black and white printers. Only plot until the system reaches steady state. Your system may have a position error, but we'll fix that later.

f) Make a plot of the estimated states versus time. (Only the estimated states!)

g) Repeat steps (c-f) keeping the state variable poles where they are but changing the observer poles to **2p** and 4**p**. (If you started with the poles at 2**p** or 4**p**, move them even farther away, like 6**p** or 8**p** or 10**p.** Try for two more locations**.**) You should notice two things: (1) as the observer poles become more negative, the observer estimated states converge more quickly to the true states, and (2) as the observer poles become more negative the estimated states are not very smooth. This is because we are now letting more noise into the system (by increasing the observer's bandwidth). Be aware that our ``true'' derivative is really just an estimate itself. You may also notice that the position is closer to what the model predicts as the observer poles move away from the imaginary axis.

h) Repeat steps (e-g) trying to ***control the position of the second cart***.

i) Now implement a reduced order observer with a state variable configuration that forces the system to be a type one system. Assume the ***positions of both carts are known*** but not the velocities. We are trying to ***control the position of the first cart***. Place the closed loop poles at [-15 -17 -19 -21 -23] and the observer poles at **p** = [-20 -25], or wherever you needed to for part c.

j) Run the ECP system with your controller/reduced order observer type 1 system configuration.

k) Compare the actual states (from the ECP system), the predicted states (from the model), and the estimated states (from the observer implemented in the ECP system). Only plot until the system reaches steady state. Your system should have near zero position error.

l) Change the location of the observer poles to **2**p and **4**p (or where ever you move them to in part g) and rerun the system. How do the results differ (if they do)?

m) Repeat steps (i-l) and try to ***control the position of the second cart***.

Your memo should contain all of your plots as attachments, with figure numbers and captions so I can follow your results.