

ECE-521 Control Systems II
Homework 8

Due at the beginning of class, Tuesday February 8, 2005

1) One degree of freedom system.

a) Implement (Simulink/Matlab) a minimum order state observer with state variable feedback for the one degree of freedom system on the web. Assume the position of the cart is a known state, but the velocity is unknown. Assume the state feedback gain is chosen so the closed loop poles are at $p = [-20 \ -30]$, the initial position and velocity of the true system are both zero, and the initial estimated velocity is -5 cm/s. You should be sure to include a prefilter. We are going to be examining the unit step response in this problem.

b) If the observer pole is at -10, you should get the response shown in Figure 1.

c) Change the observer pole -50 and rerun the system. How are the results different than for part (b)?

d) Copy your observer/controller from part (a) to new files (Copy both the Matlab and Simulink files.). In addition to this state space based model, implement an observer/controller transfer function as suggested on page 932 of the text (See example A-12-14. In this example K_a is the part of K multiplying the known states and K_b is the part of K multiplying the estimated states.) for both types of configurations (controller in the feedforward path and controller in the feedback path.) Assume for all systems that the closed loop state feedback poles are at $p = [-20 \ -30]$ and the observer poles are at -10 . Assume all initial states are zero. Note that you do not need to write your model of the plant as a transfer function (you can leave it as a state space model), though the observer/controller transfer function should be written as a transfer function. Be sure to include the proper prefilter. You should get results like those displayed in Figure 2. Turn in your plot and Matlab/Simulink code.

e) Change the observer pole to -50 and rerun the simulation. How do the results compare to those of part (d)?

f) Implement (Simulink/Matlab) a minimum order state observer with state variable feedback configuration that forces the system to be a type one system for the one degree of freedom system with the state model on the web. Assume the position of the cart is known, but not the velocity. Utilize an lqr controller, the last Q penalty value is a penalty on the new (augmented) state. Use the command $k = \text{lqr}([0.1 \ 0 \ 100], 10)$. Set the observer pole equal to -30. Assume the system is at rest and we assume the initial velocity of the cart is -5 cm/sec. You should get results similar to those displayed in Figure 3. Turn in your plot and Matlab/Simulink code.

2) Two degree of freedom system.

a) Implement (Simulink/Matlab) a minimum order state observer (not the transfer function) with state variable feedback for the two degree of freedom system on the web. Assume the position of both carts is known and the two velocities are unknown. We want to control the position of the first cart. Place the state feedback poles at $\mathbf{p} = [-15 \ -20 \ -25 \ -30]$ and the observer poles at $[-15 \ -20]$. The initial position and velocity of both carts are both zero. The initial estimated velocity of the first cart is -5 cm/sec and the initial estimated velocity of the second cart is 5 cm/sec. You should be sure to include a prefilter and rearrange the A, B, and C matrices. The unit step response is shown in Figure 4.

b) Implement (Simulink/Matlab) a minimum order state observer with state variable feedback configuration that forces the system to be a type one system for the two degree of freedom system with the state model on the web. Assume the position of both carts is known and we want to control the position of the first cart. For this problem assume we have arranged the states as **[position of first cart, position of second cart, velocity of first cart, velocity of second cart]**. Assume the estimated initial velocity of the first cart is 5 cm/sec and the estimated initial velocity of the second cart is -5 cm/sec. Place the state feedback poles at $\mathbf{p} = [-15 \ -20 \ -25 \ -30 \ -40]$ and the observer poles at $[-15 \ -20]$. You should get results similar to those displayed in Figure 5. Turn in your plot and Matlab/Simulink code.

c) Change part (b) so to control the position of the second cart. Turn in your plots.

d) Change part (c) so that we only know the position of the first cart, and want to control the position of the second cart. Place the observer poles at $[-15 \ -20 \ -25]$, and assume our initial estimate of the position of the second cart is -0.5 cm, the initial estimate of the velocities of both carts is 0 cm/sec. You should get results similar to that in Figure 6.

e) Copy your observer/controller from part (a) to new files (Copy both the Matlab and Simulink files.). In addition to this state space based model, implement an minimum order observer/controller transfer function as suggested on page 932 of the text (See example A-12-14. In this example K_a is the part of K multiplying the known states and K_b is the part of K multiplying the estimated states.) for both types of configurations (controller in the feedforward path and controller in the feedback path.) Assume we have available the position of the first cart and want to control the position of the first cart. Assume for all systems that the closed loop state feedback poles are at $\mathbf{p} = [-15 \ -20 \ -25 \ -30]$ and the observer poles are at $[-15 \ -20 \ -25]$. Assume all initial states are zero. Note that you do not need to write your model of the plant as a transfer function (you can leave it as a state space model), though the observer/controller transfer function should be written as a transfer function. Be sure to include the proper prefilter. You should get results like those displayed in Figure 7. Turn in your plot and Matlab/Simulink code.

f) Modify part (e) so the position of the second cart is known and you want to control the position of the second cart. You should get results like those in Figure 8.

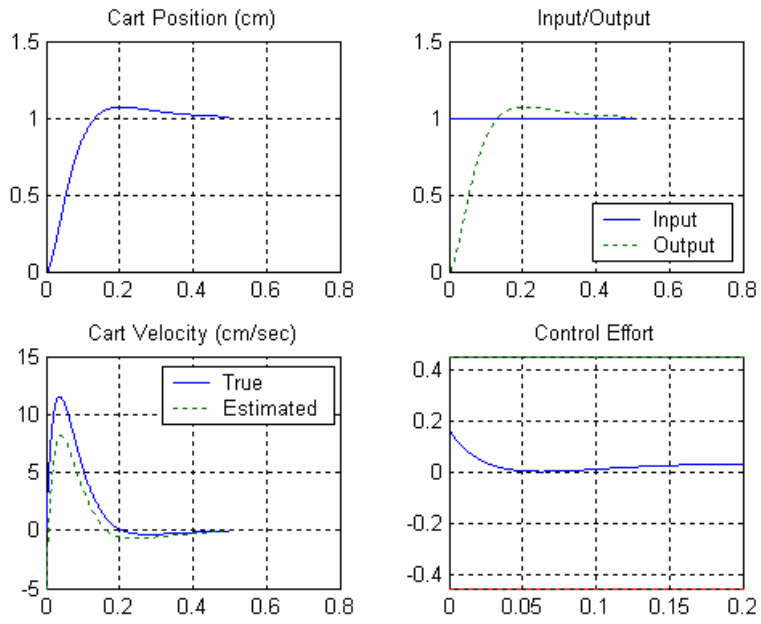


Figure 1. Results for 1b.

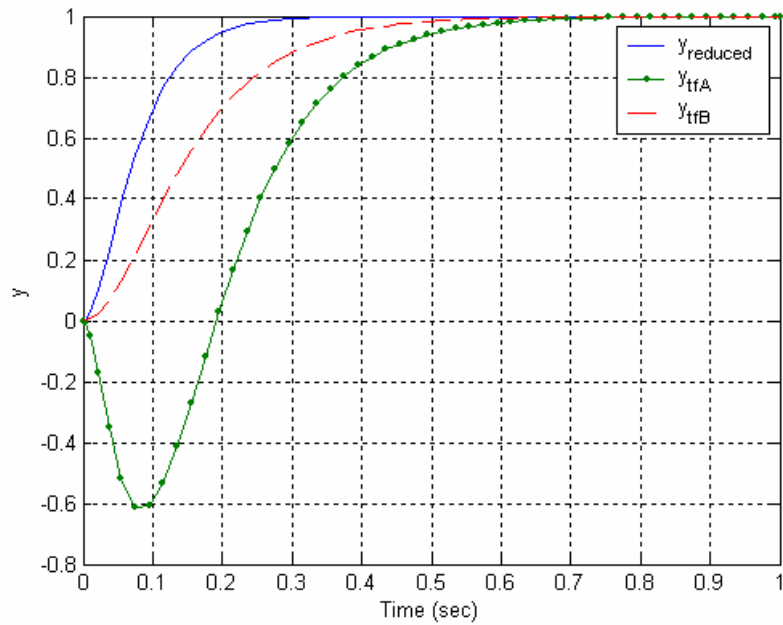


Figure 2. Results for 1d.

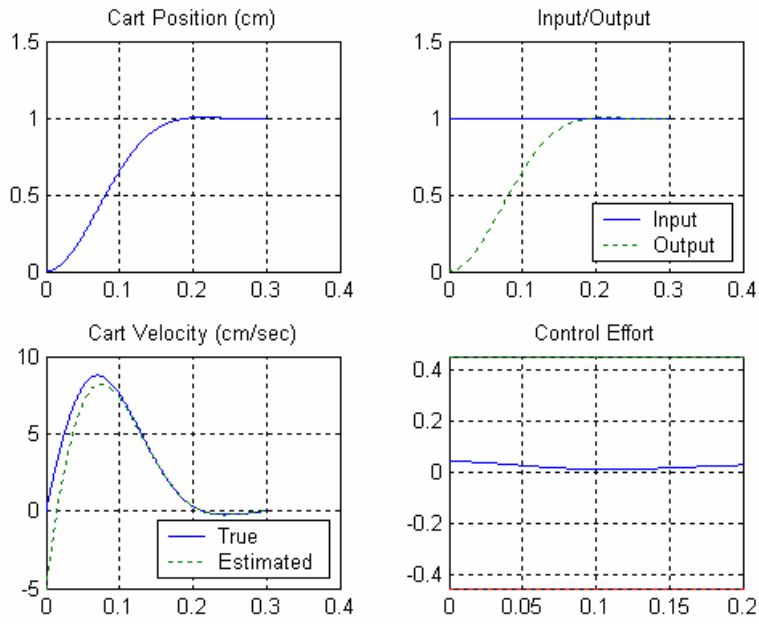


Figure 3. Results for 1f.

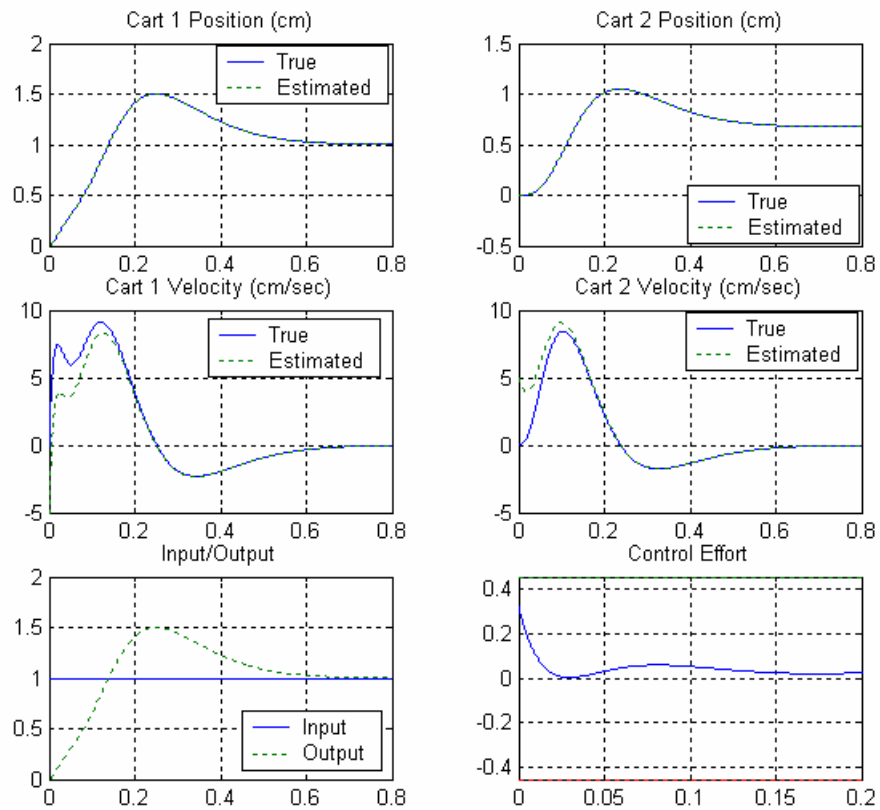


Figure 4. Results for 2a.

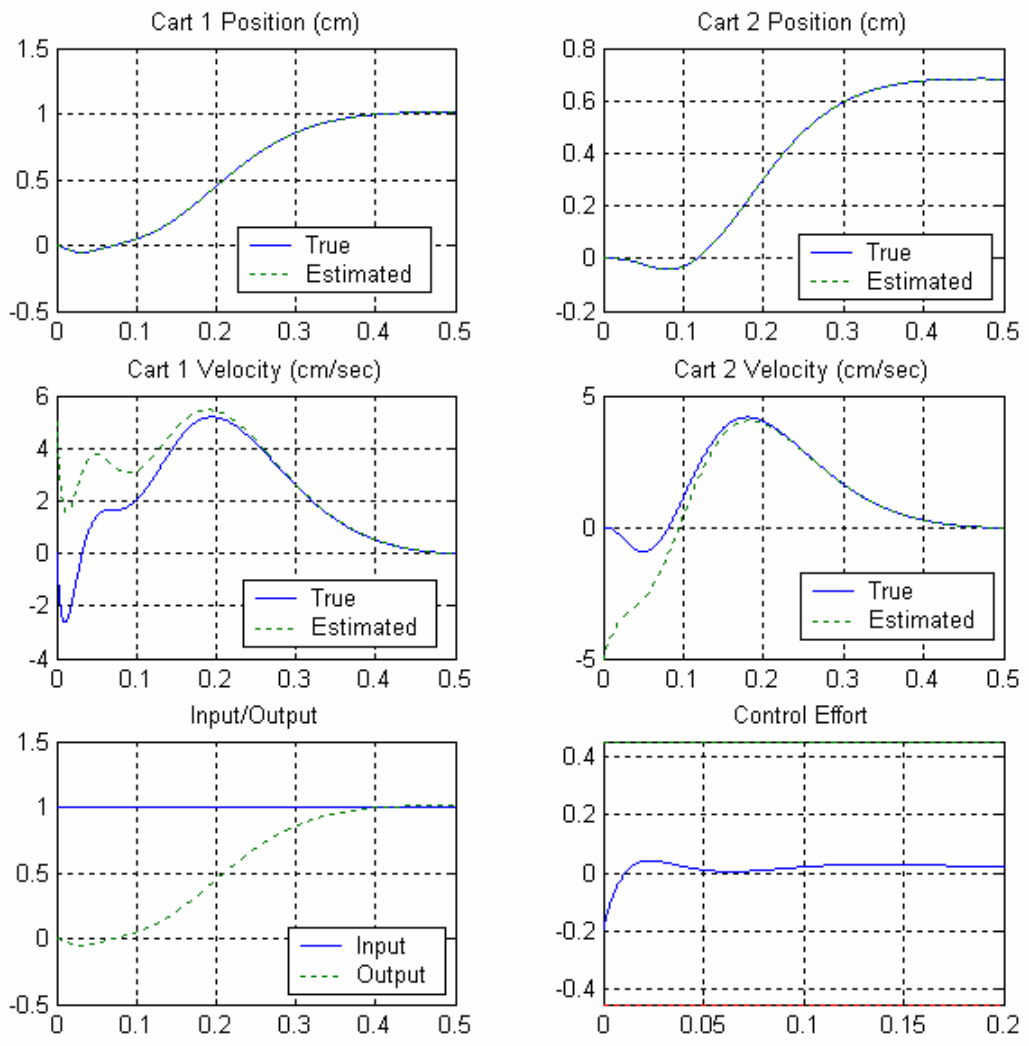


Figure 5. Results for 2b.

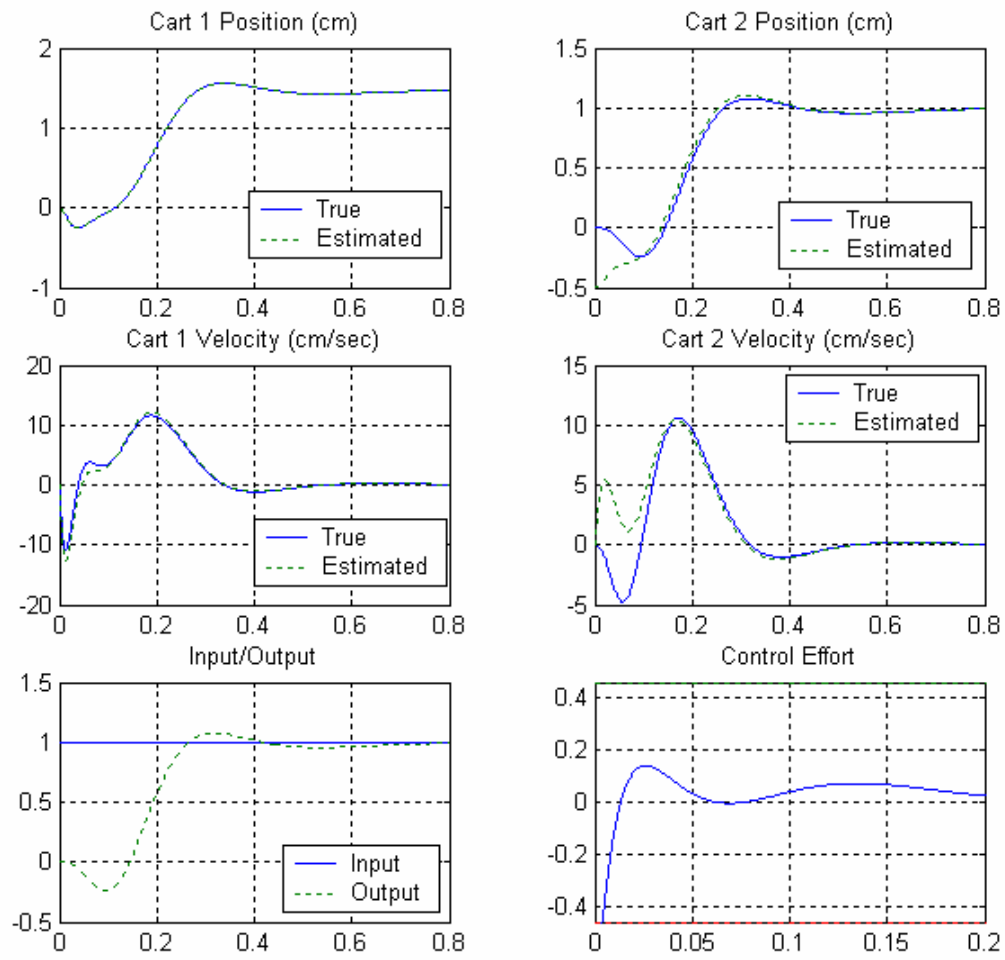


Figure 6. Results for 2d.

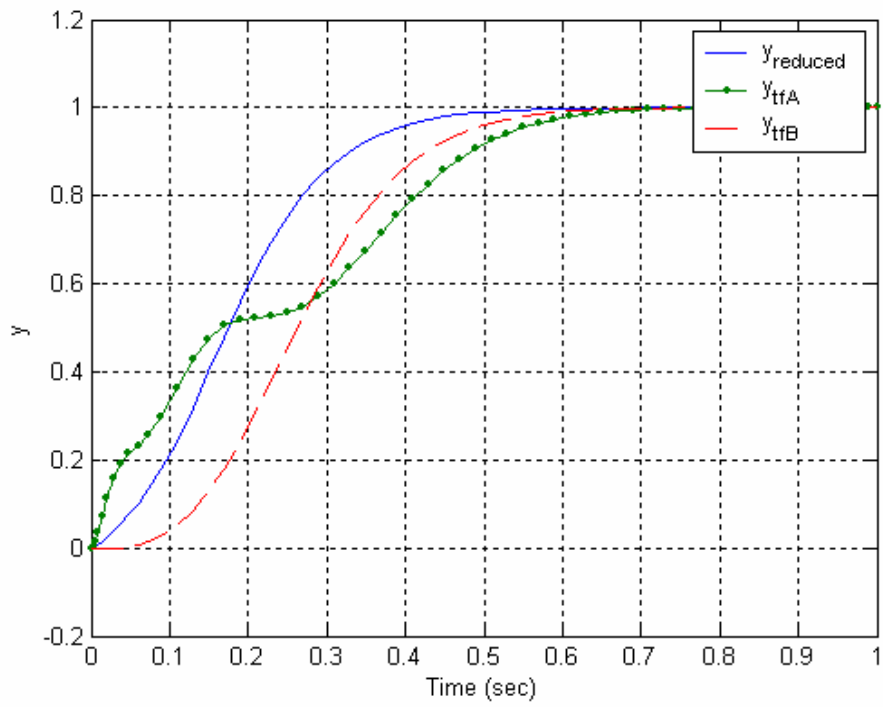


Figure 7. Results for 2e.

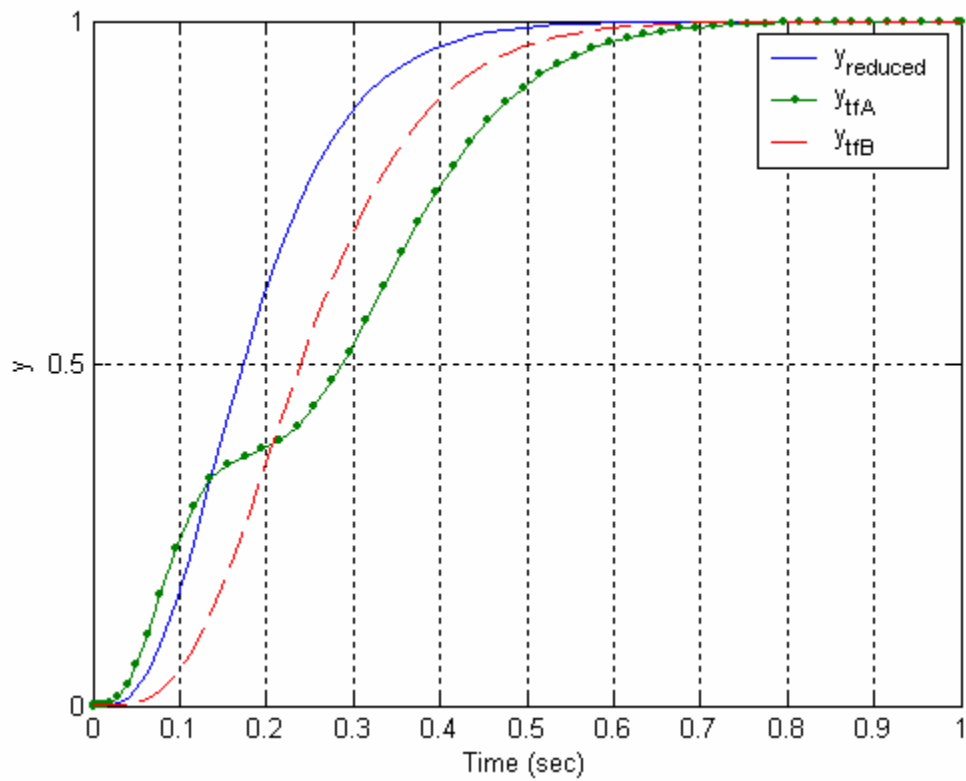


Figure 8. Results for 2f.