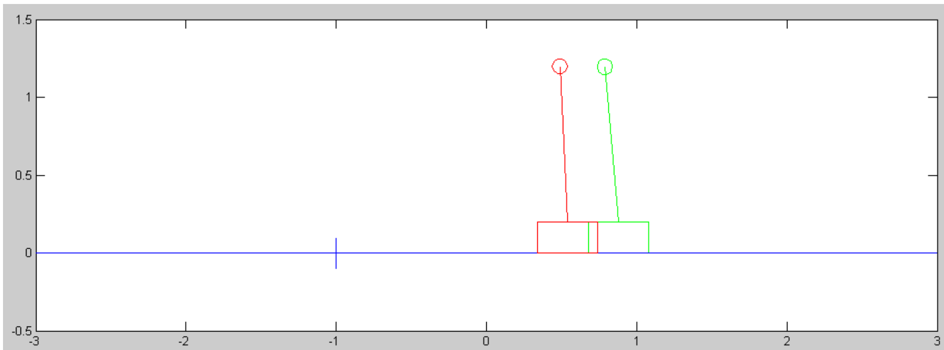
ECE 463: Homework #8

Linear Observers. Due Monday March 20th
Please submit as a hard copy, emai lto jacob.glower@ndsu.edu, or submit on BlackBoard
(corrected March 10, 2023)



Cart and Pendulum from homework #4 with a state estimator (green)

Use the dynamics for the cart and pendulum from homework set #4

$$s\begin{bmatrix} x \\ \theta \\ \dot{x} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & -29.4 & 0 & 0 \\ 0 & 26.133 & 0 & 0 \end{bmatrix}\begin{bmatrix} x \\ \theta \\ \dot{x} \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \\ -0.667 \end{bmatrix}F$$

1) Design a full-state feedback control law of the form

$$U = F = K_r R - K_x X$$

so that the closed-loop system has

- A 2% settling time of 8 seconds, and
- 5% overshoot for a step input.

Plot the step response of the linarized system in Matlab.

Assume you can only measure the cart position and beam angle.

2) Design a full-order observer to estimate all four states so that the observer is 2-5 times faster than the plant. You may use either cart position or beam angle (or both) as measurements.

3) Give the state-space model of the closde loop system using the actual states:

$$U = F = K_r R - K_x X$$

and plot the step response with initial conditions of

$X(0) = [0, 0, 0, 0]'$ $\quad X_{observer}(0) = [0.1, 0.1, 0.1, 0.1]'$

(note: use the function step3)

4) Give the state-space model of the closed loop system using the state estimates:

$$U = K_r R - K_x X_{observer}$$

and plot the step response with initial conditions of

$X(0) = [0, 0, 0, 0]'$ $\qquad X_{observer}(0) = [0.1, 0.1, 0.1, 0.1]'$

5) (20pt) Modify the cart and pendulum system to include

- your control law, and
- A full-order observer

Plot the step response of the nonlinear system + observer when

- $Xe = [0, 0, 0, 0]^T$
- $Xe = [0.1, 0.1, 0.1, 0.1]^T$