

UNIVERSITY OF CALIFORNIA, SANTA CRUZ
BOARD OF STUDIES IN COMPUTER ENGINEERING



CMPE-242:
APPLIED FEEDBACK CONTROL

HOMWORK #10
DUE 21-MAR-2017 (M-FILE TO BE EMAILED BEFORE NOON)

Note: these problems are **very similar** to the MATLAB section of the final exam. This problem set is extra credit, and will overwrite your lowest HW grade, however, I would expect you to go through this carefully in order to study for the exam. You will not be turning in a paper copy. Instead, you will turn in an m-file that completes the homework assignment. Note that this m-file is going to be extremely useful to you for the MATLAB part of the final exam.

1. *Attitude Stabilization revisited*: You are going to redesign the controller for the non-collocated plant of the satellite model, this time in state space form. We've converted the model for you, and here is the state space version of $G_{FORE}(s)$, which maps the input of the aft thrusters to the fore-body angle:

$$\mathbf{A} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.7555 & 41.9632 & 0 & 0 & 0 \\ 0 & -41.9632 & -0.7555 & 0 & 0 & 0 \\ 0 & 0 & 0 & -0.2990 & 14.9470 & 0 \\ 0 & 0 & 0 & -14.9470 & -0.2990 & 0 \\ 0 & 0 & 0 & 0 & 0 & -0.5000 \end{bmatrix}$$

$$\begin{aligned} \mathbf{B} &= [0.3329 \quad 22.9467 \quad 110.6833 \quad -85.2094 \quad 9.2657 \quad 1.9153]^T \\ \mathbf{C} &= [87.6846 \quad 0.0004 \quad -0.0001 \quad -0.0016 \quad -0.0130 \quad -15.2495] \\ \mathbf{D} &= [0] \end{aligned}$$

- a. Use LQR techniques to pick controller that yields a response similar to what you got on HW#7/8. What is \mathbf{K} ? Where are your closed loop poles?
- b. Add in the state command structure so that you can control to a reference signal. What are your two matrices, \mathbf{N}_u and \mathbf{N}_x ? Draw the block diagram of the entire control structure.
- c. Simulate the closed loop system, plot the step and impulse responses (make sure to include both output and control). Comment on how this compares to your system in HW#7/8.
- d. Pick estimator poles that are "faster" than the poles you got in (a) above, but also much slower than your Nyquist frequency, $\omega_s/2$. You will again be using a sample rate of 25Hz. What is your \mathbf{L} , where are your closed loop estimator poles? Again, draw the block diagram of the whole structure (including \mathbf{N}_u and \mathbf{N}_x).

- e. Convert your controller/estimator to a transfer function form, $K(s)$, and compare it to what you did on HW#8. Does it look the same? Check the compensator on both bode and root locus techniques (extra poles/zeros, etc).
 - f. Simulate the whole system, for a step and impulse response, and make sure to plot both y and u .
 - g. Discretize the controller/estimator to create $K(z)$, using a sample rate of 25Hz, and simulate it using the simulink files from HW#7/8. **Note:** if you do this as a transfer function, make sure to carry a whole lot of significant digits, or it won't work.
2. The state space representation we gave you in Problem 1 (above) is a transfer function directly from u (thrusters) to θ_{FORE} . In truth, we actually have measurements of both θ_{AFT} and θ_{FORE} . This only changes the [C] and [D] matrices, but they are changed to:

$$\begin{aligned}
 \mathbf{A} &= \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.7555 & 41.9632 & 0 & 0 & 0 \\ 0 & -41.9632 & -0.7555 & 0 & 0 & 0 \\ 0 & 0 & 0 & -0.2990 & 14.9470 & 0 \\ 0 & 0 & 0 & -14.9470 & -0.2990 & 0 \\ 0 & 0 & 0 & 0 & 0 & -0.5000 \end{bmatrix} \\
 \mathbf{B} &= [0.3329 \quad 22.9467 \quad 110.6833 \quad -85.2094 \quad 9.2657 \quad 1.9153]^T \\
 \mathbf{C} &= \begin{bmatrix} 21.9063 & -0.0015 & 0.0001 & -0.0053 & -0.0790 & -15.4214 \\ 87.6846 & 0.0004 & -0.0001 & -0.0016 & -0.0130 & -15.2495 \end{bmatrix} \\
 \mathbf{D} &= [0; 0]
 \end{aligned}$$

Repeat problem (1)a-1(f) with the new system, see how things change. Note that you will need to solve for your N_x and N_u matrices separately and stack them, or it won't work.