16.31 Fall 2005 - Homework 5

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Version: 2.0
Date Out: Saturday 29 October 2005
Date Due: Friday 4 November 2005 2pm

Problem 1:
DeRusso et al., Problem 3.30
Subspaces.

Problem 2:
DeRusso et al., Problem 6.2
Loss of controllability.

Problem 3:
DeRusso et al., Problem 6.3
Controllability, observability, minimality.

Problem 4:
DeRusso et al., Problem 6.9
Controller canonical form, controllability, minimality.

Problem 5:
DeRusso et al., Problem 6.12 (a)
Decomposition.

Problem 6:
DeRusso et al., Problem 6.20
Controllability, observability, Jordan form.

Problem 7:
DeRusso et al., Problem 6.21
Controller pole placement.

Problem 8:
DeRusso et al., Problem 6.26 (a), (b), (c)
Controllability and Jordan form.

Problem 9:
DeRusso et al., Problem 7.3
Observer pole placement.

Problem 10: The following dynamic matrices represent the F8 fighter longitudinal dynamics:

$$\begin{bmatrix} \dot{q} \\ \dot{u} \\ \dot{a} \\ \dot{q} \end{bmatrix} = \begin{bmatrix} -0.8 & -0.0344 & -12 & 0 \\ 0 & -0.014 & -0.2904 & -0.562 \\ 1 & -0.0057 & -1.5 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} q \\ u \\ a \\ q \end{bmatrix} + \begin{bmatrix} -19 & -2.5 \\ -0.0115 & -0.0087 \\ -0.16 & -0.6 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} d_e \\ d_f \end{bmatrix}$$

$$\begin{bmatrix} n_z \\ g \end{bmatrix} = \begin{bmatrix} 0 & 0 & -1 & 1 \\ 0 & 0 & 0.733 & 0 \end{bmatrix} \begin{bmatrix} q \\ u \\ a \\ q \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0.0768 & 0.1134 \end{bmatrix} \begin{bmatrix} d_e \\ d_f \end{bmatrix}$$

The states, controls, and outputs have been described by Dr. Paduano. The units of the angular positions and deflections (a, q, g, d_e, d_f) are radians, the pitch rate q is in rad/sec, velocity u is in ft/sec, and normal acceleration n_z is in ft/sec/sec. The goal in this problem is to create a control system for these dynamics, and investigate the step response properties of the results. You should use Matlab for the solution; please hand in all Matlab m-files and plots.

a) Plot the time response of the outputs to a step input in elevator input, d_e. Assume the initial states are zero at the beginning of the simulation, and the step input is introduced at time *t*=1. Use this step input throughout this problem.

b) Using only the elevator input, create a full-state feedback controller that places the poles in such a way to improve the dynamics of the response in part (a), while using reasonable levels of control action (note that 30 degrees of elevator deflection is large). Plot the state and output responses, as well as the elevator time history, for your control system. Provide the full-state feedback gain matrix, assuming the *physical states in the state vector above* are measured or estimated.

c) Using only the normal acceleration output (n_z), design an estimator for all the states of the system. Use pole placement to design the estimator gains, and place the estimator poles at positions that insure that the states are measured sufficiently quickly to enable the controller in part (b) to be implemented based on the estimated states. Provide the gain matrix and equations for the estimator.

d) Combine the system and estimator dynamics into a state-space system representing the overall feedback system, in which the full-state feedback gain from (b) is applied to the estimated states from (c). Plot the response of both the states and the estimated states for the full system, assuming that the initial estimates for the state is $[0.5 \quad 10 \quad 0.1 \quad 0.1]^T$ at *t*=0.

Note: Your closed-loop step responses should assume that u=-Kx+r, or *u=-Kxhat+r , where r is a reference input. The step will be applied at r in closed loop. We will discuss appropriate choice and introduction of reference inputs in future lectures.*