ASEN 5014 Project 1

Due Date: November 21, 2024

The purpose of the project is to apply control system analysis and design concepts and techniques discussed in class to a representative model of a physical system in order to gain experience with these ideas and to convey your understanding of them. Each project will be carried out individually---it must be your own work. However, you are free to discuss this with others. If you do communicate with another, be sure that you do not duplicate the design choices or any of the write-up. Otherwise, credit cannot be given. Each write-up should be typeset, and should include diagrams, equations, and figures as appropriate to explain your approach and results in each of the sections below. Diagrams and equations may be hand-written, provided they are legible and integrated into the text. Simply providing the answer is not sufficient; it must be explained. Explanations using the terminology discussed in class is expected. Provide a copy of the Matlab code used, along with explanatory comments in the code. Integrate all material in a single PDF file for submission on Canvas.

To begin, choose one of the eight physical systems posted on Canvas. Those wishing to use their own system must clear this with the instructor before proceding.

1. (20 pts) Implement the plant in Matlab. Find the plant modes. Find the Eigenspaces and real Modal spaces. Simulate the system response to a non-zero initial condition in each Modal space. Discuss the correspondence between Eigenvalues and Modal responses. Is the plant Lyapunov stable? Asymptotically stable?
2. (20 pts) Examine the reachability of the plant by determining the reachable subspace of the state space. Find an orthonormal basis for this subspace. Determine the energy required by the minimum-energy control to restore the state to the equilibrium at zero from unit-perturbations in each of the orthonormal basis vector directions for the reachable subspace.
3. (10 pts) Which of the plant modes can be changed by application of feedback control? Among these, determine desired closed loop eigenvalues (system poles) such that:
   - Closed loop eigensolutions have no oscillations
   - Close loop eigensolutions decay to zero with time constants that make sense for the application. Explain how you selected this desired time constant.
4. (30 pts) Design a state-feedback controller to place Eigenvalues (that can be placed) at the desired locations. Find the closed loop Eigenvectors and closed loop Modal spaces. Simulate the closed loop system response to unit initial state perturbations in each of the orthonormal basis directions for the reachable subspace. Compare this to the expected behavior from the choice of Eigenvalues. Compare the control signals for state feedback control to the corresponding ones (i.e. in corresponding orthogonal basis vector directions) for minimum-energy open loop control.
5. (20 pts) Construct an input gain matrix F such that reference inputs are accurately tracked by the corresponding outputs at low frequency. Simulate the response of the closed loop system to a unit step input (one input at a time if there are multiple inputs). Discuss the behavior of the step response relative to the closed loop state matrix eigenvalues.