ASEN 5014 FINAL PROJECT ASSIGNMENT
DUE: DECEMBER 15, 2021

The purpose of this project is to exercise the analysis and design tools discussed in class. **There are six required questions across 2 parts** -- please be concise in discussing your work in each of the parts below, but do describe your work in enough detail so that your reasoning, assumptions, key developments, and results can be understood. You and your teammates may discuss your work with other groups, <u>but the write up and explanations must be yours alone (CU Honor Code applies – Honor Code violations will not be tolerated)</u>. Please read and answer each question carefully.

The report must be typed (hard upper page limit of 30 pages, not including code – code must be submitted in an Appendix). You may use MS Word, LaTeX, or your favorite other word processing system. **Be sure to properly label and reference figures explicitly in the text. All reports must be submitted via Gradescope as a group (self-signup).** Remember: good basic programming practices will save you a lot of time/effort. Neatness, completeness and clarity in your submission will go a long way to helping your grade, even if you are not completely successful in answering each part.

<u>PAGE ONE DATA:</u> Please list team member names on the cover page, and provide a short list of each team member's specific contributions on the first page of the report.

<u>PART A: LINEAR SYSTEMS ANALYSIS</u>

1. [10 pts] In your own words and using correct and consistently defined notation, describe your dynamical system (plant) and define the mathematical state space model for it. Describe the system state elements, control inputs, and sensed outputs. Discuss the purpose of the physical system, i.e. what operational behavior is desired from it, and what aspects of the system you think are and are not accurately captured for this purpose by the state space model.

2. [15 pts] Building on #1 above, establish and formally define your control system objectives – this should include one or more of the following: (i) stabilization/stability augmentation; (ii) reference input tracking; (iii) disturbance rejection/cancellation. Formally define the objectives in terms of desired closed loop pole locations and/or desired time-domain response specifications for appropriate initial conditions and/or reference/disturbance inputs (justify/explain the choices). Determine the open loop plant poles. Simulate the plant response (no controller) to the desired initial conditions, reference inputs and/or exogeneous disturbances, as appropriate to your formulated control objectives. Verify that these responses make sense considering the plant poles (explain why).

3. [15 pts] Determine reachability and observability properties of your plant. If the plant fails to be completely reachable and observable, discuss how you determined which system poles can be moved with state observation/state variable feedback, and also provide bases for the reachable and observable subspaces.

PART B: LINEAR CONTROL DESIGN

4. [20 pts] Design a state feedback controller to place poles in desired locations. Simulate the closed-loop system under the desired initial conditions and/or reference/disturbance inputs used in #2, as appropriate to your design goals. Discuss whether the closed-loop response corresponds with what is expected considering the desired closed-loop pole locations. Also comment on the practical feasibility of your design, especially with respect to the amount of control effort or “actuator energy” needed to meet your design specifications. **(NOTE: DO NOT USE LQR FOR THIS PART – YOU MUST ATTEMPT A MANUAL DESIGN!)**

5. [20 pts] Design a Luenberger observer to reconstruct the state. Discuss how you determined the desired observer poles. Simulate the closed loop system consisting of observer and state variable feedback, using both zero initial observer error and non-zero initial error. Verify that the state observation error goes to zero at the desired rate in both cases. Compare the closed loop response with that obtained in #4. Comment on the practical feasibility of your design with respect to the observer gain setting and the effect sensor noise would have on control performance.

6. [20 pts] Develop an infinite-horizon cost function, and solve for the corresponding optimal state feedback law. Explain how you tuned to arrive at a final solution -- where are the closed loop poles located? Implement this (with an observer for the state) in simulation, and compare the response to that obtained in #5. How does the control effort/actuator energy of this control solution compare to that found in #4?