ME 601 Advanced System Analysis & Control — Dr. Bob

Term Project

Winter 2010

Due Thursday, 3/11/10, 9:30 a.m. **NO LATE ASSIGNMENTS WILL BE ACCEPTED!**

You must work individually only.

The term project focuses on applying what we are learning in class to a real-world system (via computer simulation). Each student must choose their own system for control (from your research project is fine); everyone must complete the same steps (see below) with their own system. A major purpose is for you to teach the class (in oral presentations) issues from the real-world. The goal of the project is to design a linear controller and a linear observer to improve the performance of your linear system. Design the controller/observer to a set of desired poles (chosen by the designer using augmented dominant 2nd-order systems ***or*** the ITAE approach).

Specific steps to complete:

0) Register your project with Dr. Bob – all projects must be unique and not related to any continuing HW or example from the book. THIS STEP IS REQUIRED!! Zero credit if your name doesn't make my list by the deadline below!
1) Determine *A*, *B*, *C*, *D* (linearized system modeling).
2) Plot the impulse and unit step responses for your open-loop, as-given system. Determine the characteristic polynomial and open-loop poles. Discuss.
3) Determine the *controllability* and *observability* of the system. If your specific system is not completely state controllable and completely observable, you must repeat steps 0/1).
4) Derive *CCF*, *OCF*, and *DCF* for your system.
5) Determine the system *stability*. If your specific open-loop system is unstable, that is fine.
6) *Dynamic Shaping*: Determine desired eigenvalues for closed-loop behavior.
7) *Controller* design: First assume that you have access to complete state feedback. Design a linear feedback controller according to your desired eigenvalues. Simulate.
8) *Observer* design: Next assume that you cannot sense some states. Design a full linear observer to estimate all the system states for your linear feedback controller. Simulate.
9) *Magnitude correction*: Ensure that your linear feedback controller and linear observer preserves the original steady-state amplitude as that of the open-loop unit step response.
10) *Simulation*: Plot the impulse and unit step responses for your designed closed-loop system. Compare to open-loop system results. In addition to output plots, also plot input effort vs. time; comment on real-world feasibility regarding required input. Apply a disturbance in MATLAB Simulink and determine how your controller handles it.

Your grade will depend in part on the oral presentation. Since time is limited you will not have time to march through steps 1 – 10 in detail. Focus on teaching the class issues you learned from this "real-world" project, and open- vs. closed-loop results. The written report must be brief yet complete.

On the day stated below starting at 9:30 a.m., each student will present their interim term project results orally to the class. An interim midterm written report is also due at that time. The midterm oral and written reports must cover steps 0 – 5 above.

On the day stated below starting at 9:30 a.m., each student will present their final project results orally to the class. The final formal technical report is also due at that time. The written report must be brief yet complete! Discussion is ***very important***!! The first page must be a MEMO detailing the results and referring your boss (me) to appropriate pages for hand calculations, plots, results, and MATLAB code. Simulink use is strongly encouraged!

ME 601 Advanced System Analysis & Control Dr. Bob

Term Project

Winter 2010

Schedule

- Register system with Dr. Bob by Thursday 1/28/10, NO EXCEPTIONS!!
- Present midterm term project results (steps 0 – 5) orally to the class and submit written midterm interim term project report (steps 0 – 5) on Thursday 2/11/10.
- Present final term project results orally to the class and submit final written report on Thursday 3/11/10.

Suggested Term Project Written Report Format

0. Cover Sheet – MEMO – serves as Abstract

1. Introduction

2. System Description and Modeling – focus on real-world aspects and simplified model

3. Analysis
    - Controllability & Observability
    - Stability
    - Similarity transformations
    - Open-loop responses

4. Design
    - Controller
    - Observer

5. Results
    - Open-loop
    - Closed-loop (compare on same plots)

6. Discussion – include real-world issues

7. Conclusion

8. Appendices (code, calculations to specify desired behavior, Simulink models, etc.)

You must include plenty of clearly-drawn figures: physical picture and/or sketch, controller/observer diagrams, result plots. Focus on the real-world issues very heavily!

Any questions? Just ask!

ME 601 Final Term Project Report Checklist, Dr. Bob

Name: ____________________________

Final report grade: ___________

______ MEMO – Abstract with details and summary; briefly discuss project. real-world system, and open- and closed-loop results.

Open-Loop

______ Real-World System
- Photo/physical diagram
- Functional diagram
- System description

______ Modeling
- Assumptions
- FBDs
- ODEs
- State-space Description
- Inputs/Outputs – identify explicitly in text and on diagrams.
- Table of parameter values

______ Open-Loop Block Diagram
- Distributed blocks with variables
- Simplified block with variables
- Numerical *A, B, C, D*

______ Open-Loop Eigenvalues (Poles) and Zeros

______ Stability

______ Open-loop performance specifications

______ Plots – unit impulse, unit step, and unit ramp responses (arranged logically); all plots must have a title and axis labels with units.

______ Open-Loop System Discussion
- Connect eigenvalues (poles) to transient response.
- Do simulated results agree with what you expect for your system?
- Real-world issues for your system.

Closed-Loop

______ Performance Specifications for Controller Design

- Rational method for determination.
- Justify relative to real-world system.
- Clearly state desired poles and desired characteristic polynomial.
- Plot transient response(s) to demonstrate desired performance.

______ Closed-Loop Block Diagram

- Distributed blocks with variables
- Identify all blocks and variables.
- Identify sensor and sensor assumptions.

______ Controller Design

- Calculate K (the controller gains).
- Determine closed loop system matrices with controller
- Closed-Loop Poles and Zeros
- Stability
- Closed-loop performance specifications – as-achieved vs. desired.

______ Observer Design

- Calculate L (the observer gains).
- Determine closed loop system matrices with controller/observer

______ Plots – unit impulse, unit step, and unit ramp responses (arranged logically); all plots must have a title and axis labels with units. On one plot, show open-, closed-, and closed-loop with observer responses. Clearly identify which curve is which. Also plot vs. time the input effort required for each controller and compare; discuss.

______ Open- vs. Closed-Loop Disturbance Responses – plot and discuss.

______ Closed-Loop Feedback Controller/Observer Discussion

- Connect poles to transient response.
- Do simulated results agree with what you expect for your system?
- Discuss input effort required vs. real-world limits.
- Discuss disturbance rejection.
- Other real-world issues for your system.

______ Professional oral presentation

______ Clear, concise technical writing

______ References

______ Appendix – MATLAB/Simulink code/diagram