AME 50652; Spring 2015; Final Project

Logistics:

1) Teams: Teams will consist of two members; there will be one team of three as we have an odd number of students. Your course grade for the final project will be your team grade. If you feel like there is a large disparity in effort put forward by team members please contact Prof. Hoelzle and we’ll adjust individual course grades accordingly.

2) Access to the lab space: Experimental apparatuses are housed in 217 MRB. The outside doors to MRB are open from 6am - 6pm. If you want access to the lab outside of these hours you will have to contact Zhi Wang or Prof. Hoelzle to arrange to be let in.

3) Computer/system access: Both the two-disk system and the balance beam are run off the same computer; hence, two different teams cannot work at once. You will be sent a google calendar invite so that you can schedule system time. Please be respectful of other teams and only schedule time that you are going to use. The computer password is ‘temp’.

4) Data storage: You can save your files to a folder on the control computer; however, there are no guarantees against these being accidently deleted. Please back up all your data in a second location.

5) Getting started: Each team will be given a blank template simulink file from which to start from. There are few settings that must be appropriately set up. Start from this file; starting from scratch may cause some difficulties.

6) Project submission: Final project submission will be in two parts. First, each team will present their control system design in a 10 min presentation the week of April 27 during class. Second, you will submit a powerpoint presentation that details your control system design to the course DropBox. It is expected that your project description is sufficiently detailed and that it would take longer than 10 mins to present; your presentation will be a
subset of the more detailed report.

Project Description:

1) **Develop a model of the physical plant [30 pts]**
   
   (a) Develop a first principles model of the system to get an understanding of the dominant dynamics. Model should be completely symbolic. If the model is nonlinear, linearize the system about a given operating point.
   
   (b) Characterize the physical system. Calibrate the sensor(s) (e.g. volts/mm, encoder counts/revolution). Characterize the sensor noise. A good way to do this is use a moving average filter to get an estimate of the ‘true’ signal and then subtract the measured signal to understand signal noise. The frequency content of the noise can be understood using the Discrete Fourier Transform.
   
   (c) Experimental system identification. There are multiple ways to get an experimental model: pseudo-random binary input and a least squares method; swept sine wave identification; simple step response. You will need to consider that both the two-disk and ball and beam systems are marginally stable. See the Appendix for notes on signal identification for a marginally stable or unstable system.

2) **Theoretical feedback control design [30 pts]** Design a feedback control system to achieve certain performance metrics. Define your performance metrics. Demonstrate your design (bode plots, simulations, etc.).

3) **Experimental implementation of design [20 pts]**
   
   (a) Convert your controller to a digital controller using Tustin’s method.
   
   (b) Implement your digital control system on the physical system. Record your controller performance and provide the necessary plots as evidence of performance.
4) **Do something extra that is interesting [20 pts]** Team choice: Build a feedforward controller, multiple controllers with a gain scheduled or bumpless transfer scheme, or do something else that is interesting.

**APPENDIX**

*Saturation Limits:* The Quanser Q8-USB data acquisition system, like many, has input / output limits: analog inputs and outputs are limited to ±10 V; encoder counts are limited to ±$X \times 10^6$ counts. The Quanser balance beam system has position limits on both the ball travel and the beam riser position.

*System Identification for Unstable and Marginally Stable Plants:* A type-1 system is marginally stable and therefore any input sent to your type-1 system will cause the output to drift in time from any imbalances in the system, leading to nonsense data. Therefore, your plant transfer function identification must be implemented within a feedback loop (Fig. 1).

**Fig. 1. Comparison between a stable type-0 system identification and a marginally stable or unstable system identification.**

The feedback loop for the Type-1/unstable system keeps the output centered around $\theta = 0$.

In this configuration your plant model should be derived from an input output relationship of your plant, not from dynamics of the entire closed loop.