Lab 4 & Semester Project: Linearization and Control System design and Implementation using MATLAB/SIMULINK and the VR toolbox - Furuta Pendulum

Dr. Randy C. Hoover
South Dakota School of Mines and Technology
EE/ME 453/553L - Feedback Control Systems
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1 Introduction

This is the culmination of the semester tied into a single system. This Lab/Project will allow you to analyze and implement all aspects of what we've learned throughout the semester. You will rely on the previous labs for *s-function* implementation and control, however rather than creating the Furuta pendulum using MATLAB plot window (as in previous labs), you will have the opportunity to explore the MATLAB Virtual Reality toolbox for visualization.

2 Getting started

The first thing you will need to do is download the "Lab4.zip" project materials. Inside the .zip folder you will find a FurutaVRModel.slx file (this is a SIMULINK model to get you started with the animation). As this is a larger Lab/Project, you will have extended time to complete it. The following list of deliverables should be included in your final document:

1. Table of contents
2. Abstract
3. Introduction
   (a) Introduction to the Furuta pendulum (to include references)
   (b) Mathematical modeling of the system (to include references)
   (c) Linearization of your mathematical model
4. Description of your control design
5. Analysis of your system (about the downward pendulum angle)
   (a) Transient behavior
   (b) Routh test if applicable for stability margins
   (c) Root locus

(d) Bode plots

(e) Nyquist diagrams

6. Performance characteristics (about the downward pendulum angle)

   (a) Time domain

   (b) Frequency domain

7. Design methodology (to stabilize the pendulum in the up position)

   (a) Phase-lag (or PI) design

   (b) Phase-lead (or PD) design

   (c) Phase-lag-lead (or PID) design

8. Final system performance simulations

   (a) Time domain

   (b) Frequency domain

9. Discussion and concluding remarks

10. References

2.1 Undergraduate Students vs. Graduate Students

To differentiate between undergraduate and graduate level instruction in this course, the undergraduate students need only stabilize the pendulum in the upright position from some "small" deviation from upright (your analysis should identify what "small" means). For the graduate students, you will be required to stabilize the pendulum in the upright configuration from **any** starting configuration. In addition, you need to drive the rotational base to zero while stabilizing the pendulum arm upright (multi-output system).

2.2 Some helpful hints

Note that the SIMULINK VR model has the upright pendulum angle as π rather than 0 (i.e., 0 is the down angle for the pendulum). You will want to linearize the system about this equilibrium point (I strongly recommend using the Jacobian method for linearization). Also note that the up position is unstable! Therefore, you should have at least some open-loop poles in the right half plane.

3 Lab Write-up

You will need to write up your lab report and provide sample screenshots with links to youtube video to illustrate your Furuta pendulum simulations are working under control. The report is to be written using LaTeX and must include a summary with each team members name along with their role in the project.

3.1 Graduate students only

You will present your analysis and design to the class on the Due date, a 10-15 minute presentation will be sufficient - similar to a conference talk.