Lab 5d: Self-Erecting Inverted Pendulum (SEIP)

I. Purpose

The goal of this project is to design a controller that starts with the pendulum in the "down" position and then swings it into and maintains it in the "up" position.

II. Theory

You already have the model of the plant when the pendulum is in the vertical position. The challenge now is to understand how to swing the pendulum up.

The key to making this work is to split the controller into two parts: one part will be the "swing up" controller while the second part will be the "balancing" controller. Once the swing up controller manages to position the pendulum almost upright, the balancing controller should be "turned on" and maintain the pendulum in a vertical state.

The way to implement this in Simulink is by using the Switch block, which is depicted below.

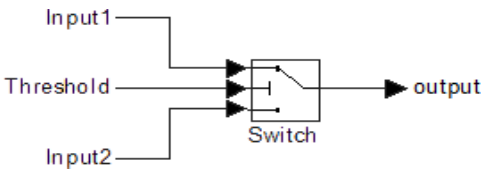

Figure 1: Simulink Switch block with all relevant signals labeled.

Its usage is pretty intuitive. It acts like a two signal multiplexor – it will pass on only one of the two inputs that it is given based on the threshold input. Make sure you double-click on the block to set your threshold value and other threshold options. This does mean that both inputs will be calculated at every time step, but you simply toss out the one you don't want to use.

Also of use will be the following two-sided saturation block, which clips the input if it exceeds the user-defined upper bound and lower bound. This can be used both to limit reference signals and to try to avoid gear stripping. For this lab, we will be using voltage limits of ±8V.

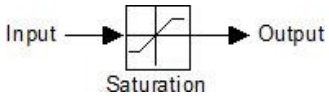

Figure 2: Simulink Saturation block with labeled signals.

The introduction of switches and the usage of different controllers based on different conditions turn this system into what is known as a **switched system**. The theory of switched systems falls under the topic of **hybrid systems**, which we will not touch on here. This is a simple and intuitive enough task to not require any knowledge of hybrid systems techniques.

At this point, you should have two or three working balancing controllers, so feel free to use whichever one you prefer. The swing up controller design is left entirely up to you.

III. Lab

Design a switched Simulink system that starts with the pendulum pointing vertically down and then self-erects and balances it vertically upwards. Your SEIP routine does not need to be perfectly robust, but should work within a few tries.

Although designing the swing up controller may seem daunting at first, the basic concepts you will need can be found in previous labs. If you're still unsure of how to proceed, try to manually erect the pendulum by moving the cart with your hand. As with any potentially complex system, debugging is best done in parts. Before putting everything together, be sure to test out smaller portions of the controller to verify proper wiring and behavior.

Based on which station you use, you will either have a long or short pendulum. The different pendulum physical properties are listed below:

Symbol	Description	Value
	Mass of pendulum (long)	0.230 kg
	Pendulum distance from pivot to center of mass (long)	0.3302 m
	Mass of the pendulum (short)	0.127 kg
	Pendulum distance from pivot to center of mass (short)	0.1778 m

More so than any of the previous labs, you have complete control over your solution, so documentation and clarity become that much more important for your lab report. Make sure you explain your reasoning and describe what each portion of your QuaRC diagram does.

There will be up to 10 extra credit points available (awarded subjectively) for robustness and sophistication of your solution (e.g., catch both ways, fastest swing up, re-erector after disturbance).

Show the GSI your working demo in lab or when you turn in your lab report.

V. Revision History

Semester and Revision	Author(s)	Comments
Fall 2010 Rev. 1.2	Jansen Sheng and Wenjie Chen	Modified some descriptions on the requirements.
Fall 2009 Rev. 1.1	Justin Hsia	Rewrote lab to allow more freedom for student solutions.
Summer 2008 Rev. 1.0	Bharathwaj Muthuswamy	Initial lab write-up.