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EE 502 – Fall 2022

October 21, 2022

**EE 502 Project Proposal**

**Goals of my project**:

* Build a real-life working demo of an inverted pendulum system
* Implement a variety of different controllers (P controller, PID, Lead/Lag, and/or LQR) in MATLAB and/or on a physical microcontroller to balance the pendulum
* Implement the High-and-Low Gain Approach (Saberi, 1996) for an inverted pendulum with restricted travel, in MATLAB and/or on physical microcontroller
* Implement an open-loop technique, where once the pendulum is nearly balanced, the cart will move back and forth, which keeps the cart and pendulum near the origin (s=0, θ=0)
* Report on some of the inherent difficulties in building a physical system
  + Lack of sensors:
    - Only have one sensor for theta, need to estimate theta\_dot, sensor has finite resolution (2048 pulses per revolution)
    - No position sensors, so we estimate position by counting the number of pulses to the actuator (stepper motor is precise enough for our purposes
  + Actuator is not directly applying a force to the cart/pendulum system: instead, it is moving a belt which is attached to the cart
  + Estimating system parameters, such as the effective length of the pendulum and mass
* Bonus: implement a swing-up in MATLAB and/or on my pendulum demo

**Progress so far:**

* Derived equations of motion for a cart and pendulum system
* Linearized equations of motion around a nominal trajectory
* Simulated LQR controller in MATLAB (single and double pendulum on a cart)
* Designed and built cart and pendulum system, mostly 3D printed
* Wired the actuator (stepper motor), sensor (rotary encoder), and programmed the microcontroller (ATMEGA328P)
* Implemented a P-controller in software, can balance the pendulum for 3.5 minutes (<https://youtu.be/ivcoI8oz12Q>)
* Implemented the high-and-low gain approach for an inverted pendulum in MATLAB. Was able to reproduce figures from the 1996 paper.

**Related Papers**

* Z. Lin, A. Saberi, M. Gutmann and Y. Shamash, ``Linear controller for an inverted pendulum having restricted travel -- A high-and-low gain approach," Automatica . Vol.~32, No.~6, pp.~933-937, June 1996
* Minho Park, Yeoun-Jae Kim, Ju-Jang Lee, “Swing-up and LQR stabilization of a rotary inverted pendulum”, Artif Life Robotics, Vol. 16, pp. 94–97, 2011