ECEN 4213 Embedded Computer Systems Design

October 7, 2021

Lab #: 03

Topic: PID Ping Pong Ball Control

Final Report

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1 Introduction

Lab 03, "PID Ping Pong Ball Control", of ECEN 4213 is designed to introduce students to digital range sensors and PID control on the Raspberry Pi 4. PID control is useful to solve linear control problems which do not require any safety assurances. Under the right circumstance, it can also be applied to nonlinear systems. This usually requires cascaded PID controllers and high frequency update loops. Students are given the following tasks to complete:

- Implement a sonar sensor
- Implement PID control

By the end of Lab 03, students will have learned to implement basic PID control on a Raspberry Pi 4. These techniques will provide a framework to develop more complicated projects utilizing GPIO functionality of the Raspberry Pi family.

2 Exercises

Lab 03 is divided into two independent assignments. This section details the results of each assignment.

2.1 Exercise 2: Sonar Sensor

Relevant code included in the zipped file. Note that rather than use the provided code structure, we designed a separate SONAR class (found in sonar.cpp and sonar.hpp) that manages the sonar interface on its own thread. This was for simplification of the main loop and compatibility with future labs.

2.2 Exercise 3: PID Ping Pong Ball Control

Relevant code found in zipped file. Similar to exercise 1, we created separate PID and ADC classes within (pid.cpp, pid.hpp, adc.cpp, and adc.hpp) for modularity and to promote code reuse. The main code simply initializes an instance of a sonar, PID controller, and adc in its setup.

3 Supplemental Questions

1. Briefly summarize what you learned from this lab.

We learned how to interface with an ultrasonic distance sensor. We then combined that knowledge with previous experience controlling DC motors to regulate a ping pong ball's position in a tube. We implemented a PID controller and saw how to tune it gradually to obtain a desired performance.

2. In PID control, how will the values of the P, I, and D parameters affect your control performance?

Higher P increases overshoot but decreases rise time. Higher I decreases steady state error but can contribute to overshoot. Higher D reduces overshoot and brings the plant to the setpoint faster, but increases the effect of noise in the measurements on the output.

3. How did you decide the value of the P, I, D parameters to achieve a good control performance?

We set I and D gains to 0. We then arbitrarily started with a P gain of 10. After observing the controller performance, we began adjusting the P gain until the ball would reach near the setpoint in a reasonable amount of time. At this point, we began slightly increasing the integral gain to reduce oscillation and steady state error. Next we added a small amount of D gain to eliminate the overshoot we were experiencing when moving the ball large distances. After that, we simply adjusted the gains in small amounts until we were satisfied with the controller's performance.

4 Acknowledgments

I certify that this report is my/our own work, based on my/our personal study and/or research and that I/we have acknowledged all material and sources used in its preparation, whether they be books, articles, reports, lecture notes, and any other kind of document, electronic or personal communication. I/We also certify that this assignment/report has not previously been submitted for assessment anywhere, except where specific permission has been granted from the coordinators involved.

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