Exploring Regression for Two Wheeled Self Balancing Robots

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***Abstract*—Two Wheeled Self Balancing Robots (TWSBR) have long been used in education as an application of control theory. TWSBRs can be modeled as inverted pendulums, which are nonlinear unstable systems. This sort of system requires a robust method of control to stay as close as possible to a steady, balanced state. Often, the method of control chosen for these systems is PID. Recently, there have been efforts to use more complicated control methods within the machine learning domain, such as support vector regression or reinforcement learning. This paper aims to investigate if data collected from an adequately tuned PID controlled TWSBR can be used to train regression models, and further determine if these models can be used by the TWSBR to self-balance.**

I. Introduction

TWSBRs are inherently unstable systems. The equilibrium point is extremely small, which means constant small adjustments must be made to keep the system near equilibrium. The motor response required does not have a linear relationship with the current estimated angle, which further requires that a robust control algorithm be used.

Instead of designing an entire robot platform, a Polulu Baloboa 32U4 Balancing Robot kit was used. This platform was selected due to its well designed pcb, high performing components, and community support. The Balboa ships with a balancing algorithm installed that only used the system's gyroscope. However, for a previous work, a PID algorithm was developed that combined both gyroscope and accelerometer readings to balance. The models in this paper solely used output data sampled from this PID algorithm.

II. Background

Past works have investigated various machine learning techniques to control a TWSBR. G.S. Krishna et al. [1] compared a hand-tuned PID algorithm to a Reinforcement Learning (RL) model that was based on the advantage Actor-Critic (A2C) algorithm. E. Li et al. [2] used RL on a modeled TWSBR system simulation with combined simulation and real world data to reduce model bias once applied to a real world system. L. Cui et al. [3] used a Support Vector Regression model to control the TWSBR.

Each of these prior works have a catch. [1] was able to run its RL model on the TWSBR locally, though it used a much more powerful ESP32 microprocessor in relation to the Atmega32U4 on the Balboa. [2] verified their model within a simulation, and didn't apply it to a physical robot. [3] had their TWSBR send state information wirelessly to an upper computer where the model was run, and then its output wirelessly sent back to the TWSBR. The goal of this paper is to determine if regression models are able to be trained off of real world data, then ran locally on the low power Atmega32U4 as part of the Polulu Balboa in order to self-balance.

III. Methods

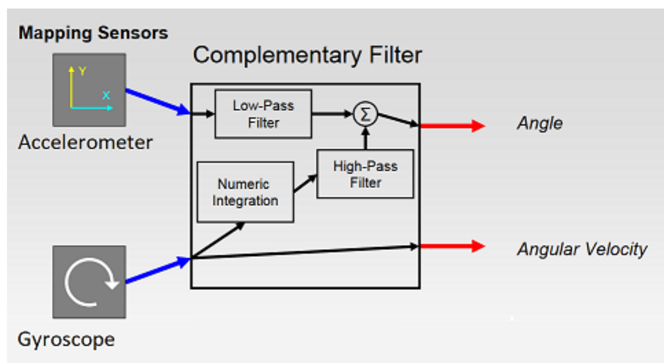

Fig. 1. Block Diagram of Balance Filter (adapted from S. Colton "The Balance Filter: A Simple Solution for Integrating Accelerometer and Gyroscope Measurements for a Balancing Platform" June 2007).

This section gives an overview of the PID algorithm used for the robot's control, describes the method of collecting sample data, the different regression models trained, and how the models were integrated into the robot's control.

The most important portion of a PID controller is defining and using an error signal. In this application, the error represents the difference between the current angle estimate and the target angle. For this paper, the target angle was defined as 0 degrees. The PID calculation is part of a control loop that samples gyroscope and accelerometer sensor data, performs transformations on the data, calculates a response, and transmits data wirelessly every 2 milliseconds.

To determine the error, an angle estimate must first be made. The angle estimate used is based on the Balance Filter proposed by S. Colton [4] and shown in Figure 1. The Balance Filter is a complimentary filter that combines gyroscope and accelerometer readings into one estimate of angle. Both sensors are used because singularly they each have a problem. The gyroscope is susceptible to drifting over time, and the rate it drifts changes, so it cannot be compensated for with a constant value. The accelerometer data has a lot of high frequency noise. By combining each sensor's data using a complimentary filter, both the gyroscope's drift and accelerometer's noise are mitigated. The output of the filter is integrated over each control loop iteration, and this becomes the angle estimate. The angle estimate, instantaneous angle rate from gyroscope, and integration of the angle are fed into the PID input, then the response from the PID function is sent directly to the motors.

To create the regression models, data must be sampled from the robot. Each control loop iteration, the robot's angle estimate, instantaneous angle rate, integration of angle, and motor response are sent wirelessly via bluetooth to a PC for capture.

The first regression model used was linear regression. To be continued...

REFERENCES

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