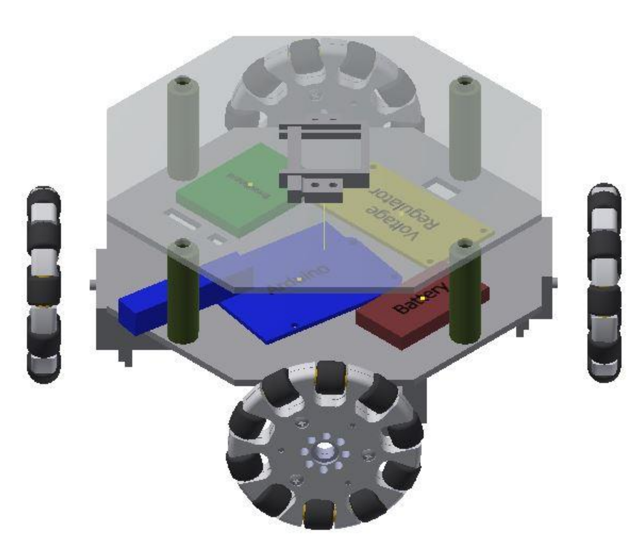
Omnidirectional Segway

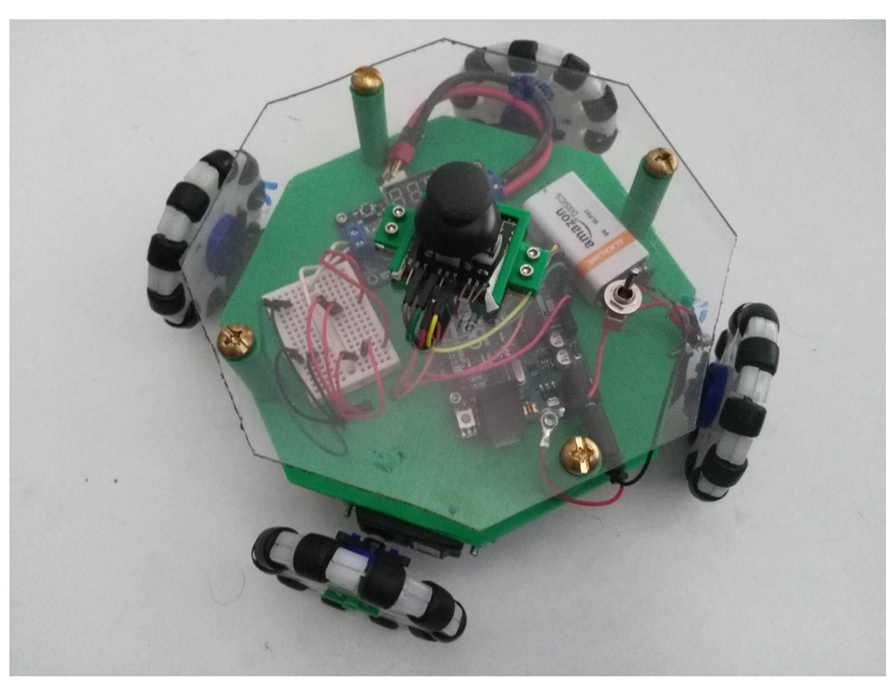
Kumar Veeravel, Mechanical Engineering
Mentor: Dr. Nolan Tsuchiya
Kellogg Honors College Capstone Project

Introduction

The purpose of this project was to create and stabilize an inverted pendulum on two axes. An inverted pendulum is an extremely well understood unstable problem. Generally however it is only stabilized in one dimension seeing as the two axes can be independently stabilized. This project, however, has a base that moves to stabilize the pendulum in 2 axis, similar to how a Segway is an inverted pendulum with 1 axis of instability

Mechanical Design

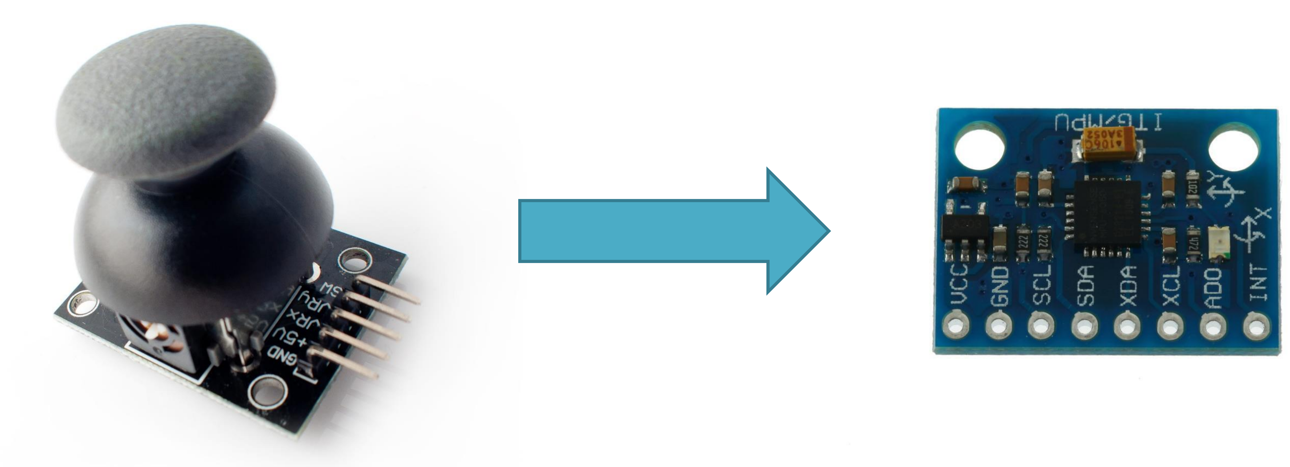




The mechanical design aspect of the project focused on creating a system that had the capacity to actuate two axes instead of one. A standard Segway is essentially an inverted pendulum with 1 degree of freedom. In the case of a Segway, however, the both the system, and the means of actuation are inherently unstable. The difference with this design is the actuation method, the base, which is stable. The plant itself is unstable, and additionally like a Segway, both the actuation method and the plant itself move. This project was mainly designed and constructed with a 3d printer. The design for the base uses omni wheel drive which allows for movement in all direction in a plane, and the actuation is through continuous rotation servo motors to allow for open loop control of the motors themselves.

Sensors

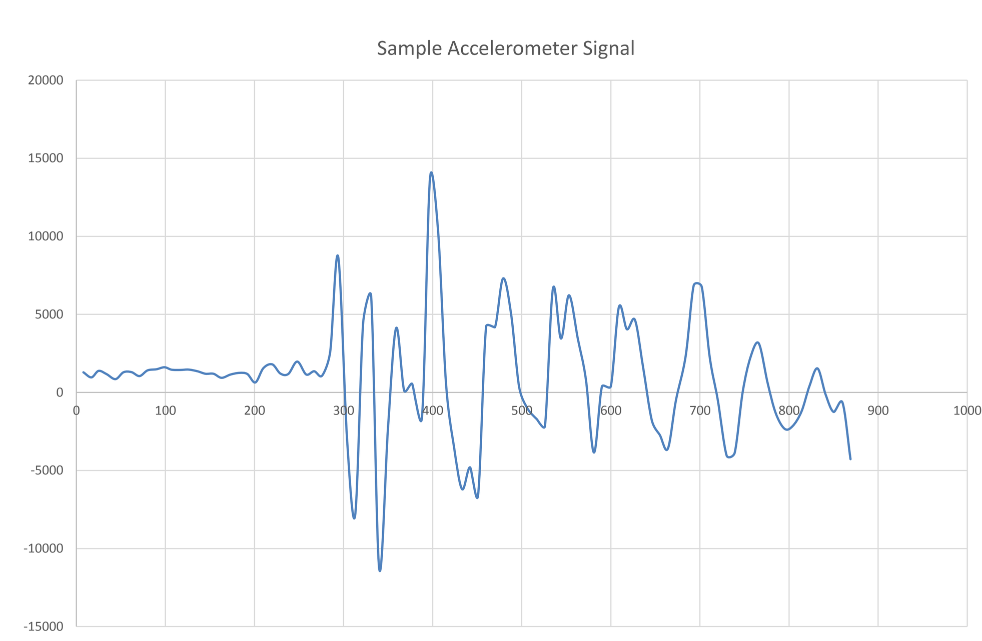
One big setback in this project was the sensor that was being used. Initially an analog controller was used both as the 2 degrees of freedom, and as the sensor to determine angle, but in the PID tuning stage it was discovered that this was not adequate due to a dead zone at the center of the analog stick. An internal measurement unit (IMU) was used to replace the analog sensor as the sensing element after this discovery.

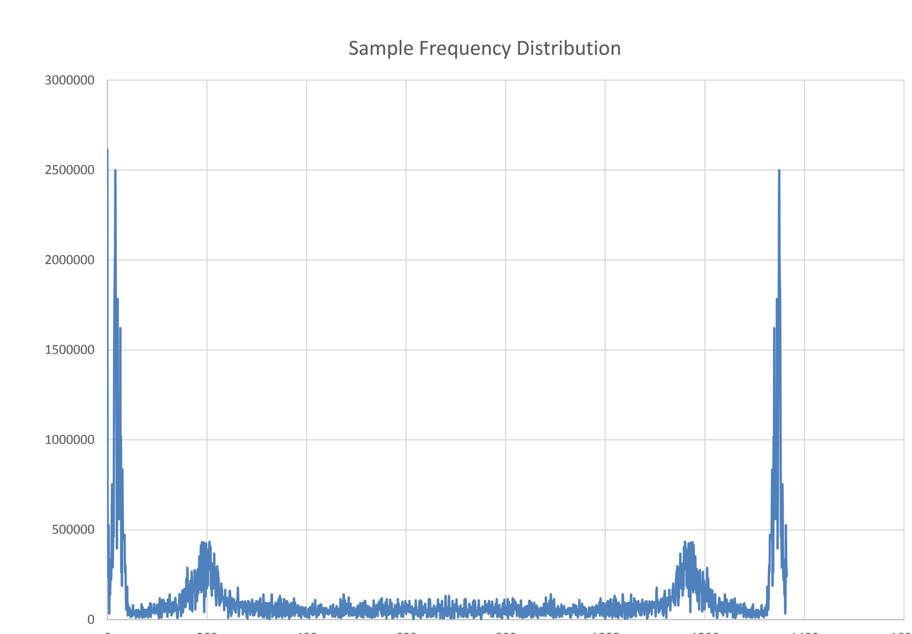


Control System

The control systems portion of this project is the data acquisition, data filtration, and PID control system. The data acquisition is through an IMU placed at the center of mass of the pendulum. This IMU contains acceleration as well as gyroscope data. This data is taken and filtered with a Kalman filter on the Arduino microprocessor to produce a value for the angle relative to 90 degrees, in both the x and y directions. This angle is the measure of error in the system, and is used in the code as part of a PID control system to send actuation signals to the 4 motors at the base.

Data Acquisition





The above graphs illustrate the issue with the raw signal from the accelerometer. The graph on the left shows the signal, and the graph on the right shows the decomposition of the signal into its frequencies.

Filtering

The There are several different methods to filter the data. The sensor that was used was an IMU. This sensor has a 3-axis accelerometer, and a three-axis gyro. This data can be filtered in several ways. A complimentary filter weights the combination of acceleration data and gyro data, and the pure acceleration data and sums the two for every instance of time. A Kalman filter on the other hand uses past data as well as current data to estimate the measurement. A third way that this data can be filtered is by passing the acceleration data through a low pass filter. This method, however, does not utilize all the sensing capabilities of the IMU. For this project a Kalman filter was used.