Wheeled Bipedal Robot

Brian Boxell

Advisors:
Prof. Mohammed Mahdi Agheli Hajiabadi, William Michalson

Wheeled Robots

Pros:

- Mechanically Simple
- Power Efficient
- Elementary Kinematics
  - Easy to control
- Stable
- High Speeds

Cons:

- Can not do Stairs
- Usually Limited to Smooth Surfaces

Left: iRobot Roomba: https://www.irobot.com/en_US/roomba.html?
Right: Boston Dynamics Sand Flea: https://www.bostondynamics.com/legacy

Legged Robots

Pros:

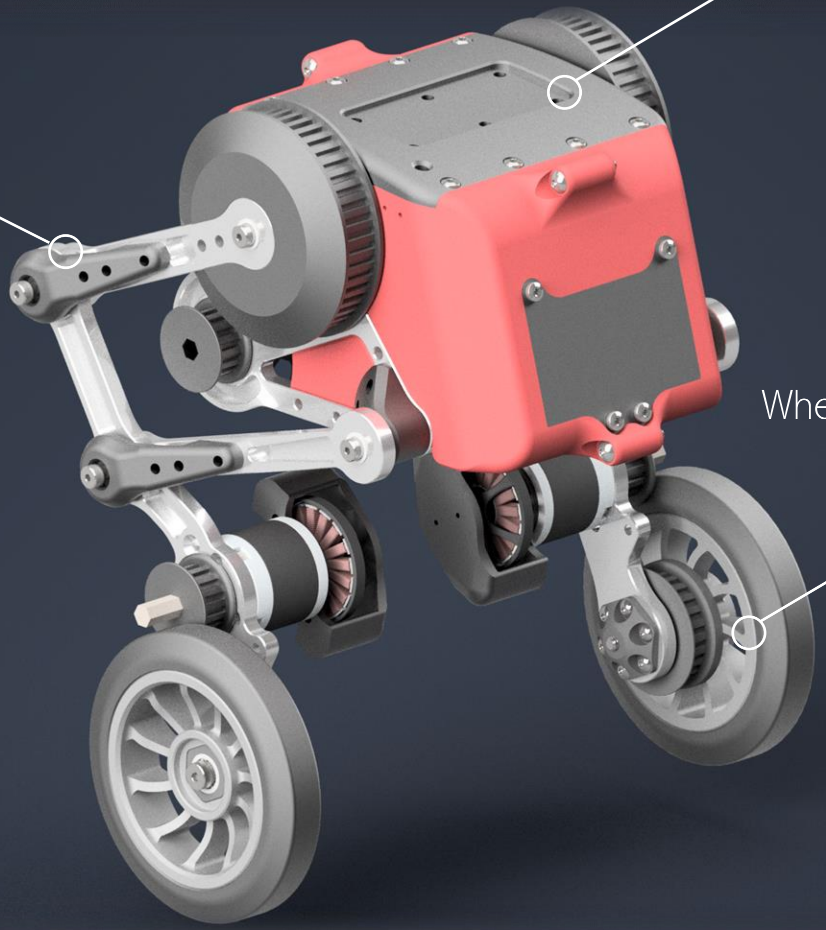
- Kinematically Similar to Humans
- Exotic Terrains

Cons:

- Mechanically Complex
- Kinematically Complex
- Unstable
- Computationally Expensive
- Power Inefficient
- Slow
- Low Payload

Left: Boston Dynamics Spot: https://www.bostondynamics.com/products/spot
Middle: Boston Dynamics Atlas: https://www.bostondynamics.com/atlas
Right: ETH Zuich ANYmal: https://www.directindustry.com/prod/anybotics/product-233413-2330048.html

Introducing: Scout



Objective: Explore the effectiveness of combining wheels and legs in a compact mobile robot platform.

Mechanical Design Requirements

- Highly Robust and Durable
  – Aluminum, Ball Bearings, Steel Shoulder Bolts
- Low-Backlash Power Transmission
  – Belt Reductions with Tensioners
- Low-Slop Linkage Joints
  – Preloaded Joints with Ball Bearings
- Easy to Maintenance
  – Compartmentalized and Modular
- Designed for Manufacturing (DFM)
  – All 3D Printed or Machined in WPI Washburn Shops

Linkage Design

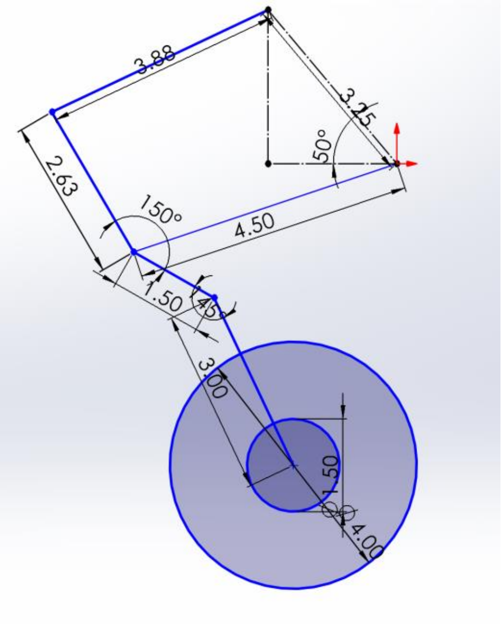
Ideally, the body moves linearly

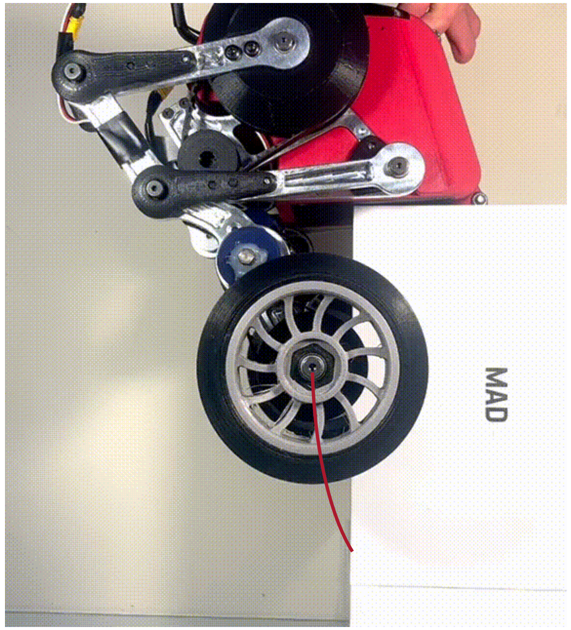
- Reduces the horizontal variance of COM throughout path

The balance control can compensate for non-linearity.

- If the COM shifts during height adjustment, the robot can drive to compensate.
- The angle of the on-board sensors changes throughout travel

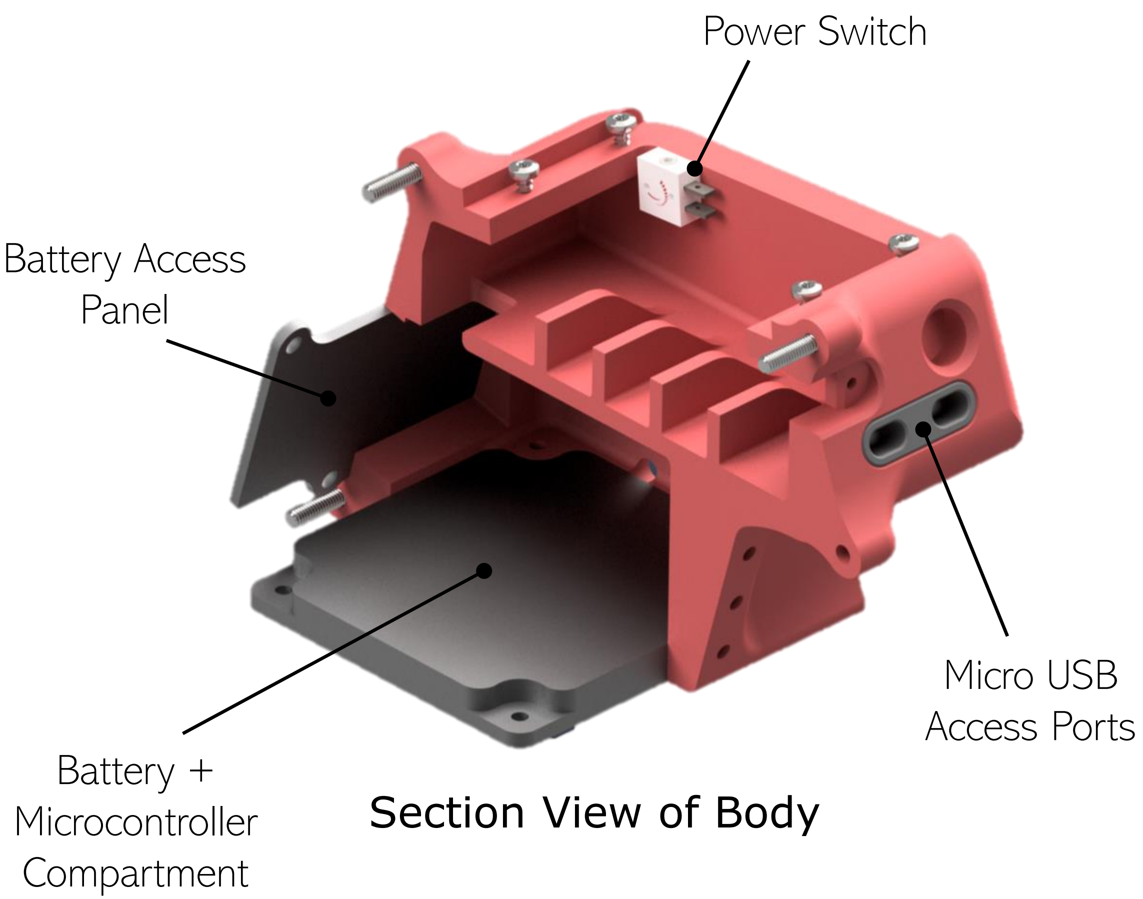
Materials: Aluminum 6061, PLA+, Ball Bearings





The legs at Various Points of Extension

Body Design



Section View of Body

Compartmentalized Body

Upper Compartment:

- Power Distribution
- Motor Controllers
- Voltage Regulation

Lower Compartment:

- Battery
- Microcontroller
- IMU, Receiver

Material: PLA+

Motors + Servos + VESCs

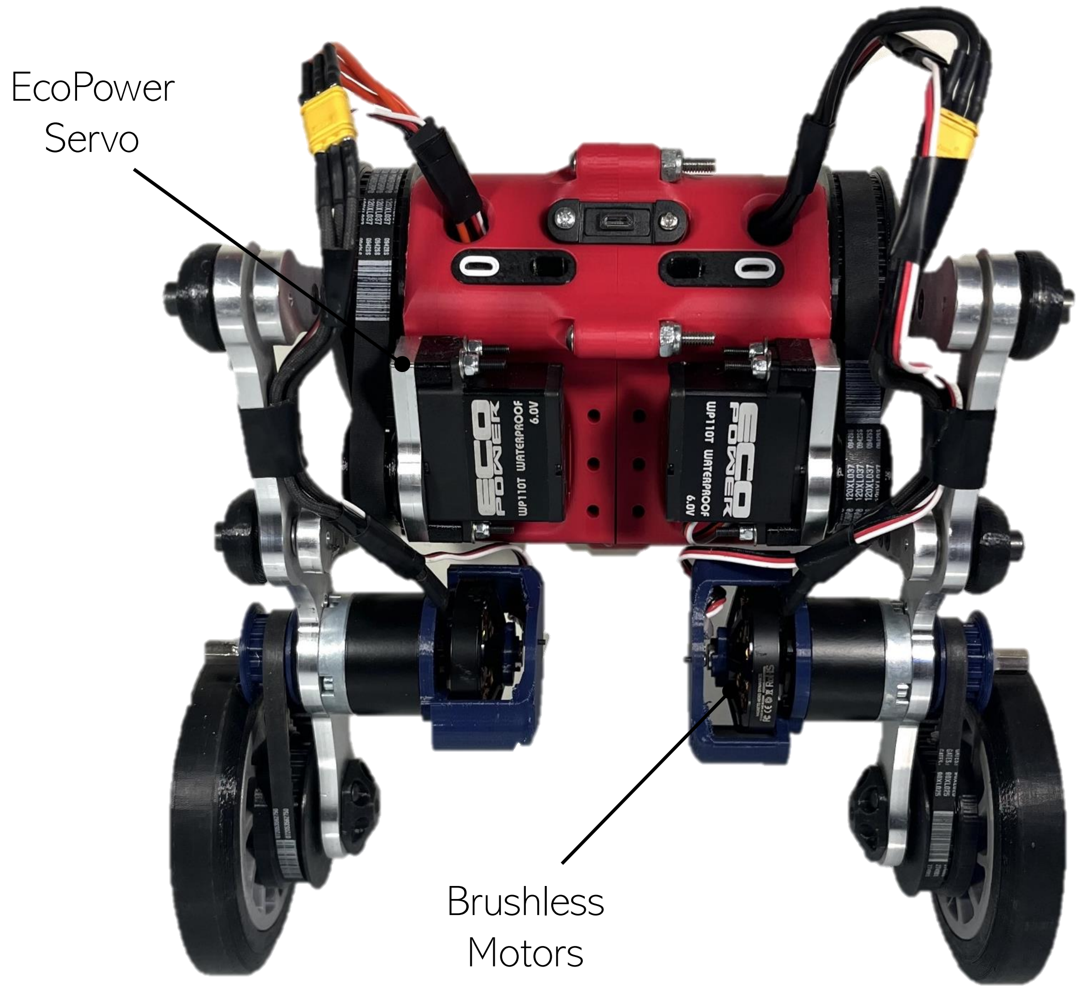
Robot Weight: ~4.5lbs

Leg Linkage:

- Required: 504oz-in (2x SF)
- 2x EcoPower 110T Servos
  - 288oz-in each

Drive Wheels:

- Required: ~104oz-in (2x SF)
  - To hold steady at ~3°
- 2x MAD Components 4008 250kv
  - 19:1 Gearbox
  - 80oz-in each, Output = 1500oz-in
  - Max Speed: 3.85ft/s (4” Wheel OD)
- VESC A50S Motor Controllers



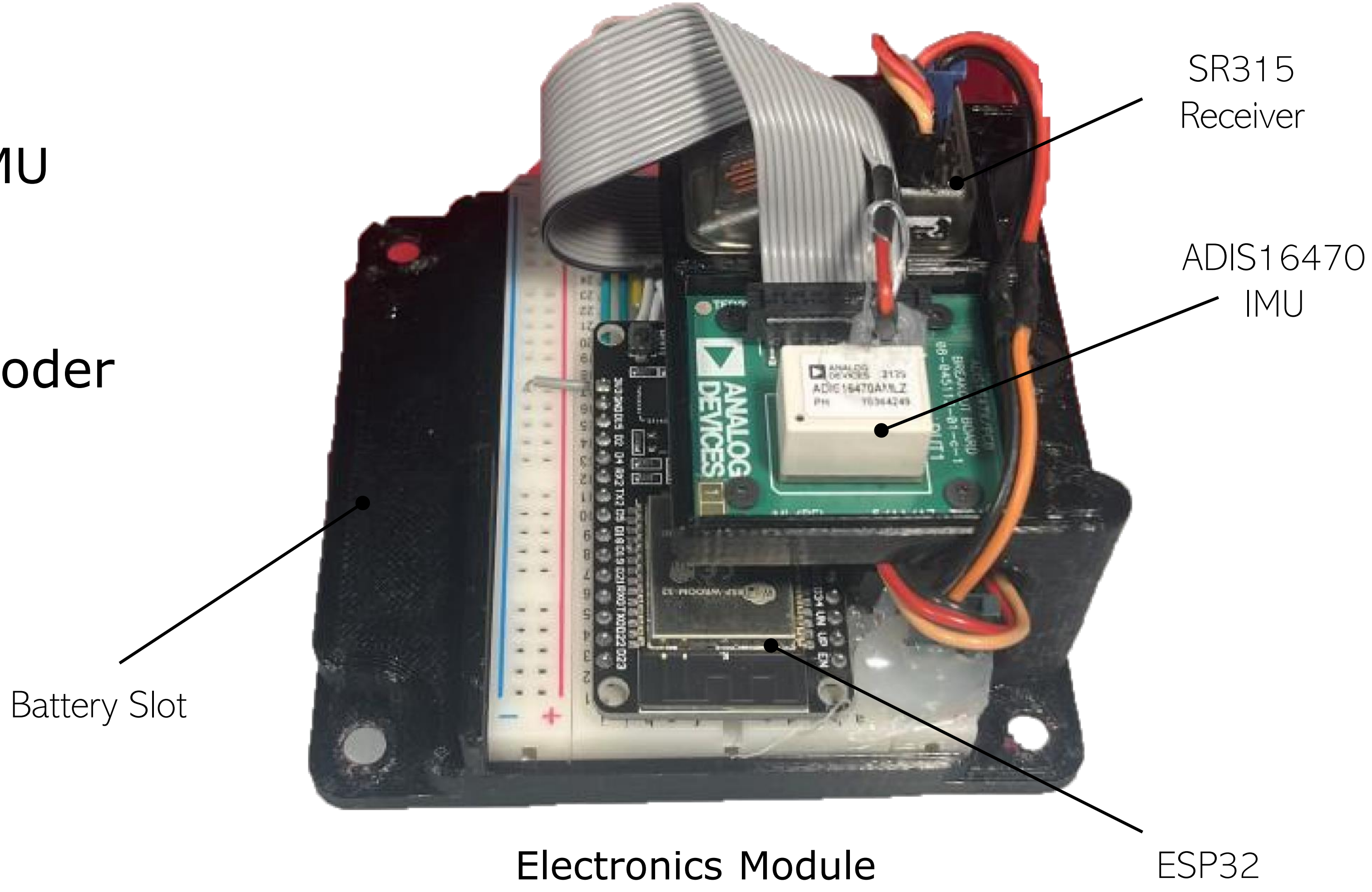
Sensors + MCU

Two Main Sensors:

- Analog Devices ADIS16470 IMU
  - Kalman Filter
  - Data In via SPI
- AMS AS5048A Inductive Encoder
  - Wheels
  - PWM Interface

Microprocessor: ESP32

- Built-in Bluetooth + WiFi
- Supports I2C + SPI
- 34 GPIO Pins

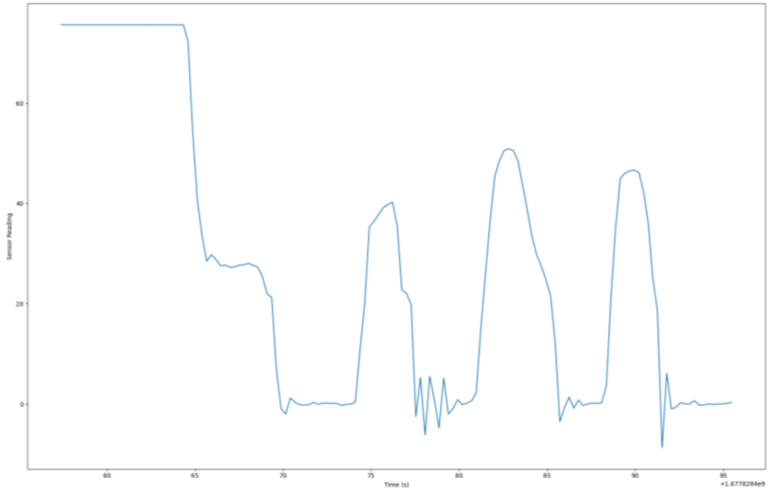


Electronics Module

General Software

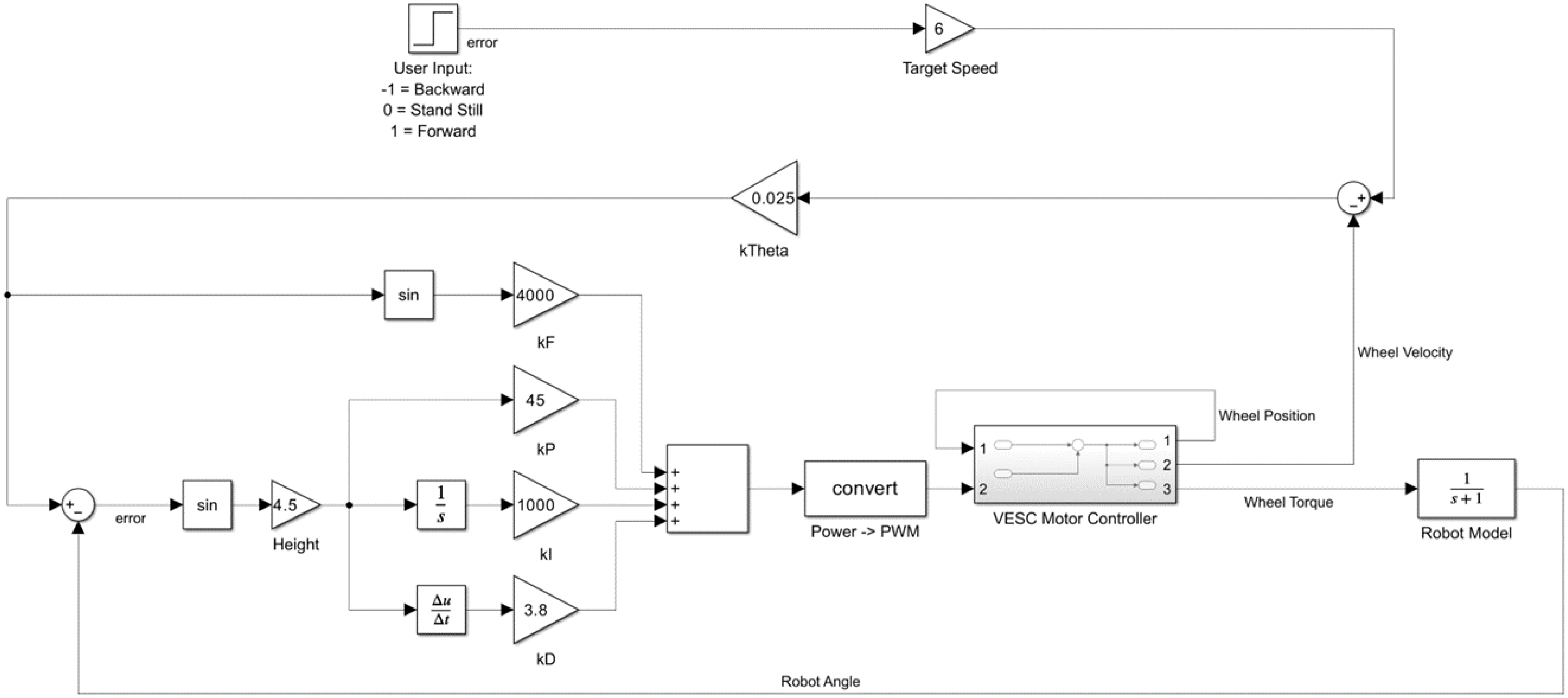
Primarily C++ over 14 classes/files, 3000+ lines of code:

- Kalman Filter
  - Combine Gyro + Accel
- SPI Transfers
  - Optimized for reading IMU
- Custom Interrupt Priorities
- Bluetooth Serial Connection
- Keyboard Input
  - Allows for advanced input functions
- Input from RC Controller
  - Primarily used for remotely driving the robot
- Datalogging
- Data Visualizer
  - Plots sensor Data in Real Time with MatPlotLib
- State Machine
- PWM Output Structure
- Custom VESC Firmware Release
  - Accepts PWM Encoder Input



Example Real-Time Data View

Balance Controller



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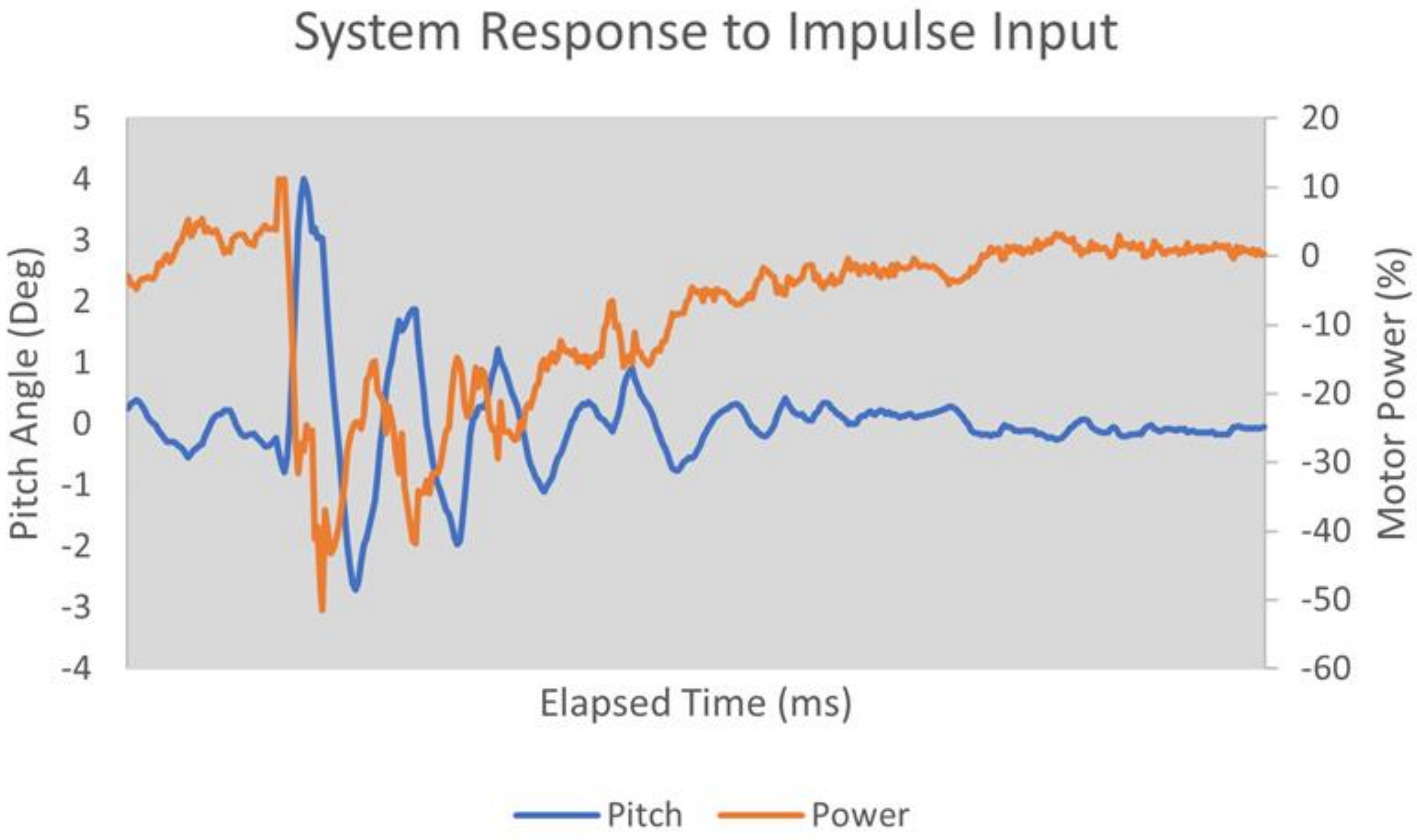
Example Transient Response



Response to poking the robot while it is balancing.

- Clear deteriorating oscillation
- Low steady state error

Scout On The Move!

Results

Measured Data:

Maximum Robot Speed:	1.4ft/s
Max Recoverable Displacement:	3.5°
Failure Rate:	1 per 14min
Max Extension:	3”

Improvements:

- Stability while changing heights
- Stability with payloads
- Replace gearboxes to reduce backlash

Acknowledgements

Professor Agheli and Professor Michalson

For supporting me through the project and giving me the opportunity to pursue an interesting and difficult problem.

Analog Devices

For donating an IMU that was critical to this project's success

William Stanley + Seems Reasonable Robotics

For assisting in creating a custom VESC release

Evelyn Maude

For helping me debug a painful SPI issue

The WPI Combat Robotics Club

For teaching me new skills, encouraging me to be creative, and pushing me to follow through every project to the best of my ability