Wheeled Bipedal Mobile Robot

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Motivation

Wheels are historically the most common method of locomotion for robots because they are simple to implement and are power efficient. However, wheeled robots tend to struggle with exotic terrain like stairs and rocks, which is a significant limitation for real-world tasks. One classic solution to this is legged robots, but legs are mechanically complex, computationally expensive, and less efficient, especially when exotic terrains only make up a small fraction of the total use cases of a mobile robot. This project explores the effectiveness of combining wheels and legs to create a highly dynamic, versatile, and efficient mobile robotic platform.

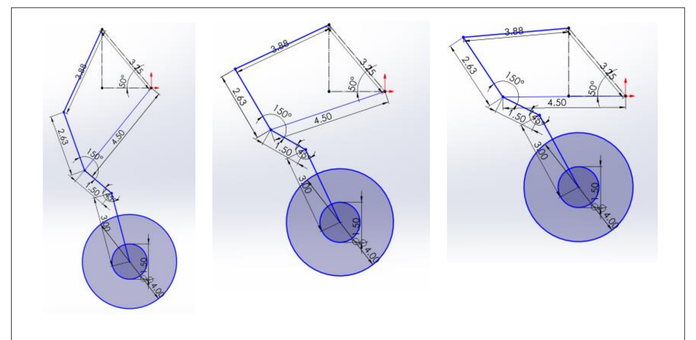
Hardware Design

CAD Design done in Solidworks 2022, machined in the WPI Washburn Shops.

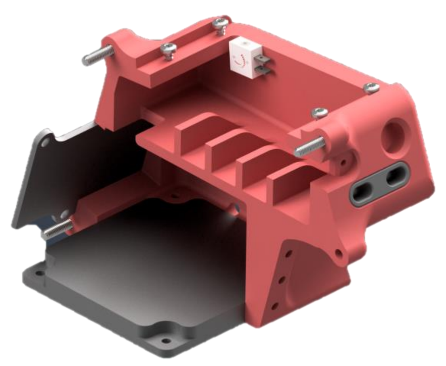
Linkage Design

4-bar linkage that approximates linearity in the wheel path.

Materials: Aluminum 6061, Steel Shoulder bolts, Ball Bearings



Linkage Position at Multiple Heights



Half Section View of Body

Body Design

Separate battery and motor controller compartments.

Easy access micro-USB ports.

Materials: 3D Printed PLA+

Power Train Design

Low backlash belt reductions and Long Robotics 19:1 Planetary Gearbox.

Max Speed: 1.92 ft/sec

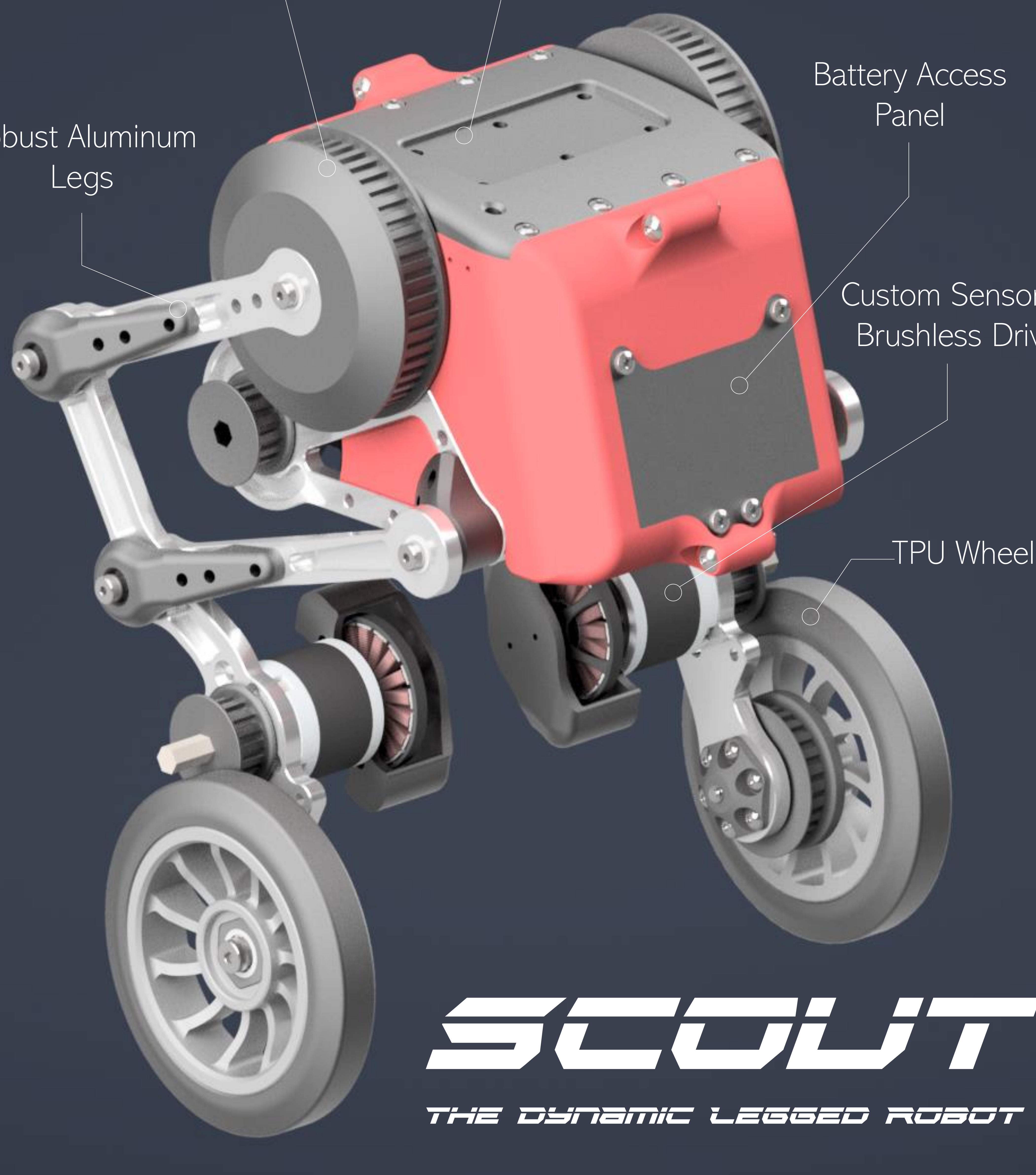
Materials: Neoprene Belts, 85A TPU Tires, PETG Wheels, PLA+ Pulleys

Software Architecture

Framework: C++ on PlatformIO with Arduino Framework

Core Functions:

- IMU Kalman Filter
- SPI Transfer on Interrupt
- Custom Interrupt Priorities
- Custom VESC Firmware
- Bluetooth Keyboard Input
- Bluetooth Real Time Datalogging
- Python Data Visualizer Tool
- Core State Machine
- PWM Motor Output

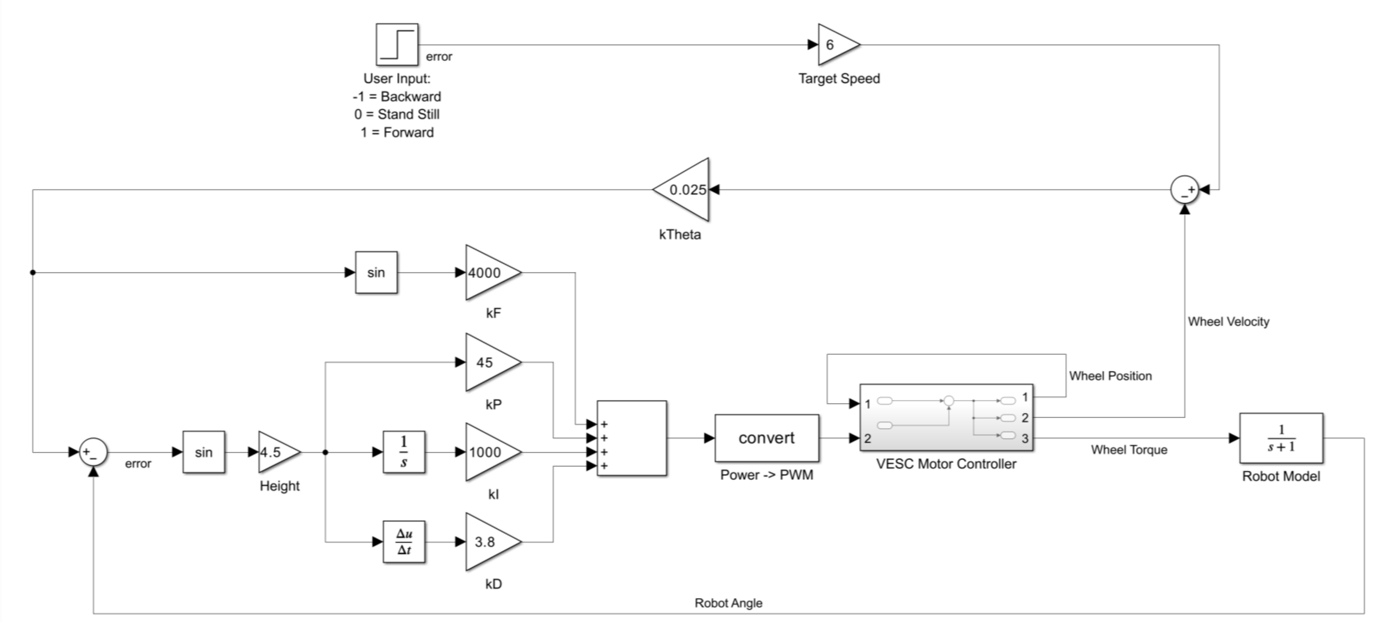


Electronics Architecture

Microprocessor: ESP32 Dev Board
Motor Controller: A50S VESC V2.2
Drive Motor: MAD 4006 250kv
Leg Motor: MAD 5008 170kv
Battery: 4s 850mah LiPo
5V Power Supply: iFlight Micro BEC
Wheel Encoders: AS5048A
IMU: Analog Devices ADIS16470 over SPI

Controls

Balance Controller Block Diagram



Leg Linkage Controller

PD Control: *Maintain Height*

- Control Variable: θ_{leg_crank}
- Setpoint: Desired Position for Leg Height

P Control: *Stabilize in Roll*

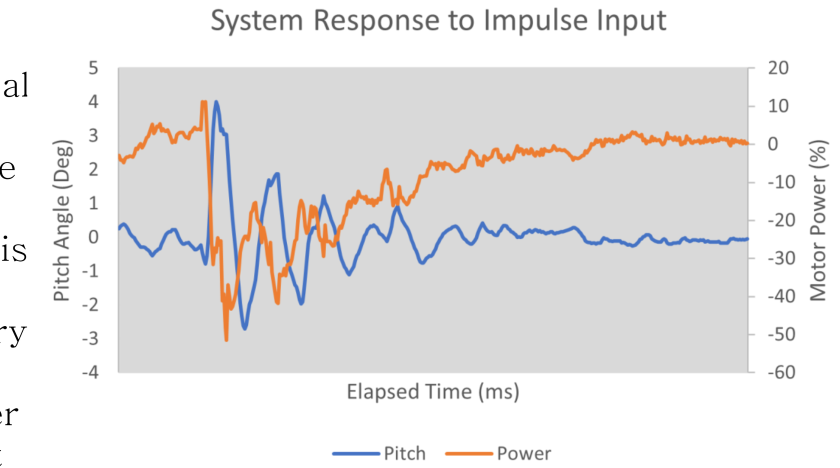
- Control Variable: θ_{robot_roll}
- Setpoint: $k * (\omega_{left} - \omega_{right})$

Conclusions

This project built a functional platform from the ground up.

Key Findings:

- Low-end torque is critical for balancing. Cheap brushless motors provide poor low-end response.
- IMU error accumulation is critical
- Reducing backlash is very important for balancing
- Maximizing the controller refresh rate is important



This project proves the feasibility of dynamic balancing on wheels as an effective form of locomotion. It shows the feasibility of combining wheels with height changing legs to create a versatile mobile robot.