Project WatchDog: Autonomous Pet Rescue Robot

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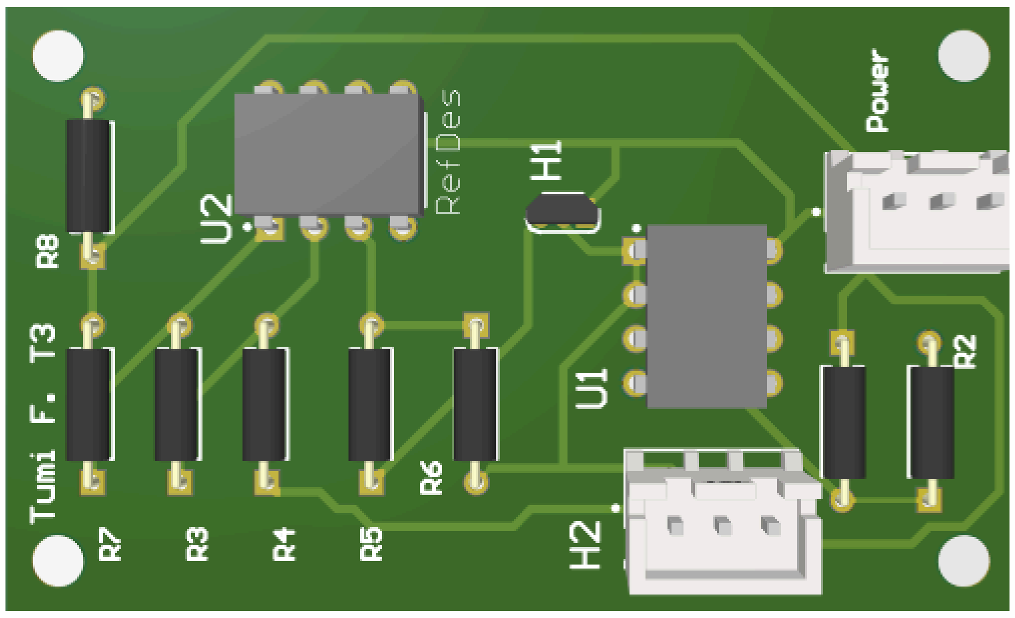
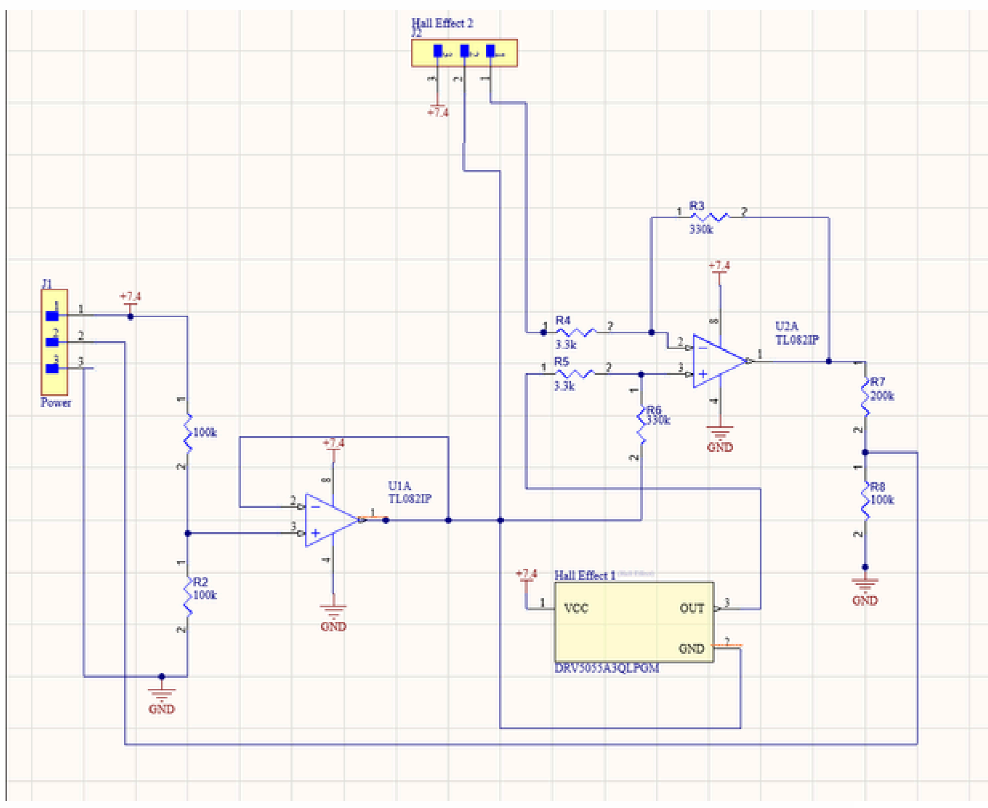
Project Overview

Project WatchDog was developed for the ENPH 253 Summer Robotics Competition at UBC, tasked with autonomously navigating a complex playing field, locating magnetic "pets," and returning them to a safe zone within two minutes. The robot integrated multiple subsystems, including LIDAR-based navigation, a custom PCB with differential Hall effect sensors for pet detection, and a mechanical arm to retrieve pets and place them in a basket for transport back to the safe zone.

A lightweight logging system using Node.js and multicore ESP32 programming captured sensor data, robot states, and pet counts in real time, enabling efficient debugging and strategy optimization. The structural design included motor mounts, pet basket hooks, sensor brackets, and spools, all 3D-printed and optimized for strength, weight, and modularity. This combination of mechanical engineering, electronics, and software enabled the robot to achieve one of the top performances out of 16 teams, rescuing 5/7 pets.

Individual Contributions



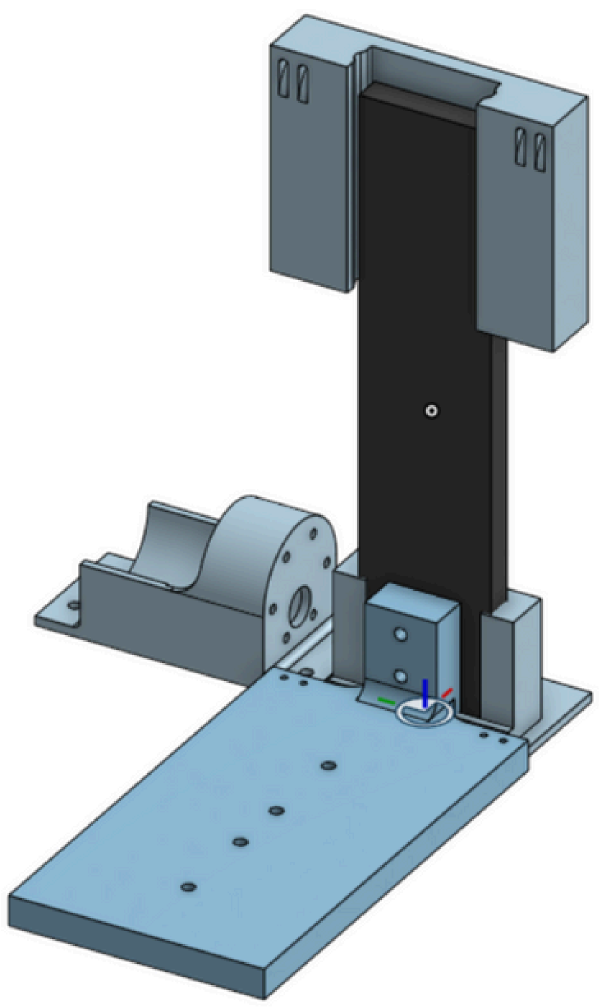


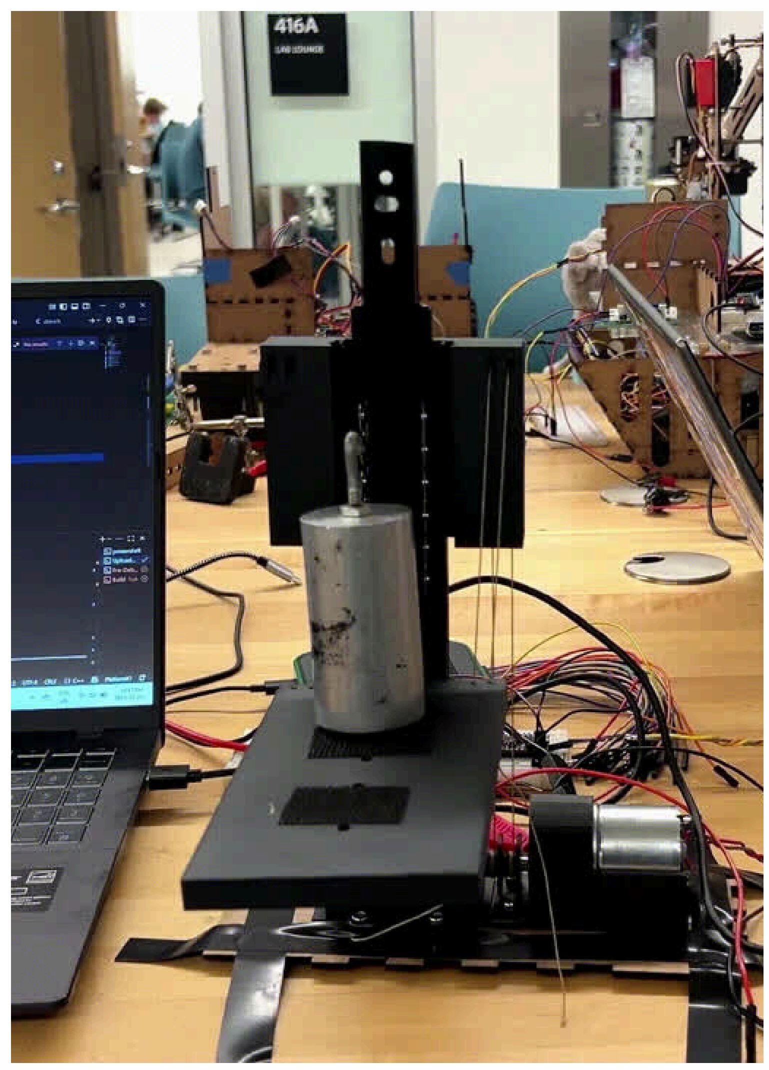
Pet Detection PCB

- Designed a custom pet detection PCB using a differential amplifier circuit and dual Hall effect sensors to reliably detect magnets embedded in the "pets."
- Hall effect sensors measure magnetic field strength, but since they also pick up the Earth's magnetic field, we used a differential measurement strategy: taking the difference between two spatially separated sensors allowed us to subtract out the background field and isolate the field generated by the embedded magnets.
- Created the PCB in Altium Designer, ensuring optimal sensor placement, noise mitigation, and proper grounding to reduce signal interference.
- Outsourced PCB manufacturing abroad and performed full manual assembly and soldering of SMD and through-hole components.
- Wrote embedded C++ firmware for the ESP32 to handle sensor calibration, real-time data acquisition, and integration with the main control system.
- Achieved a high detection accuracy with minimal false positives, enabling consistent pet localization during competition runs.

Lift Mechanism

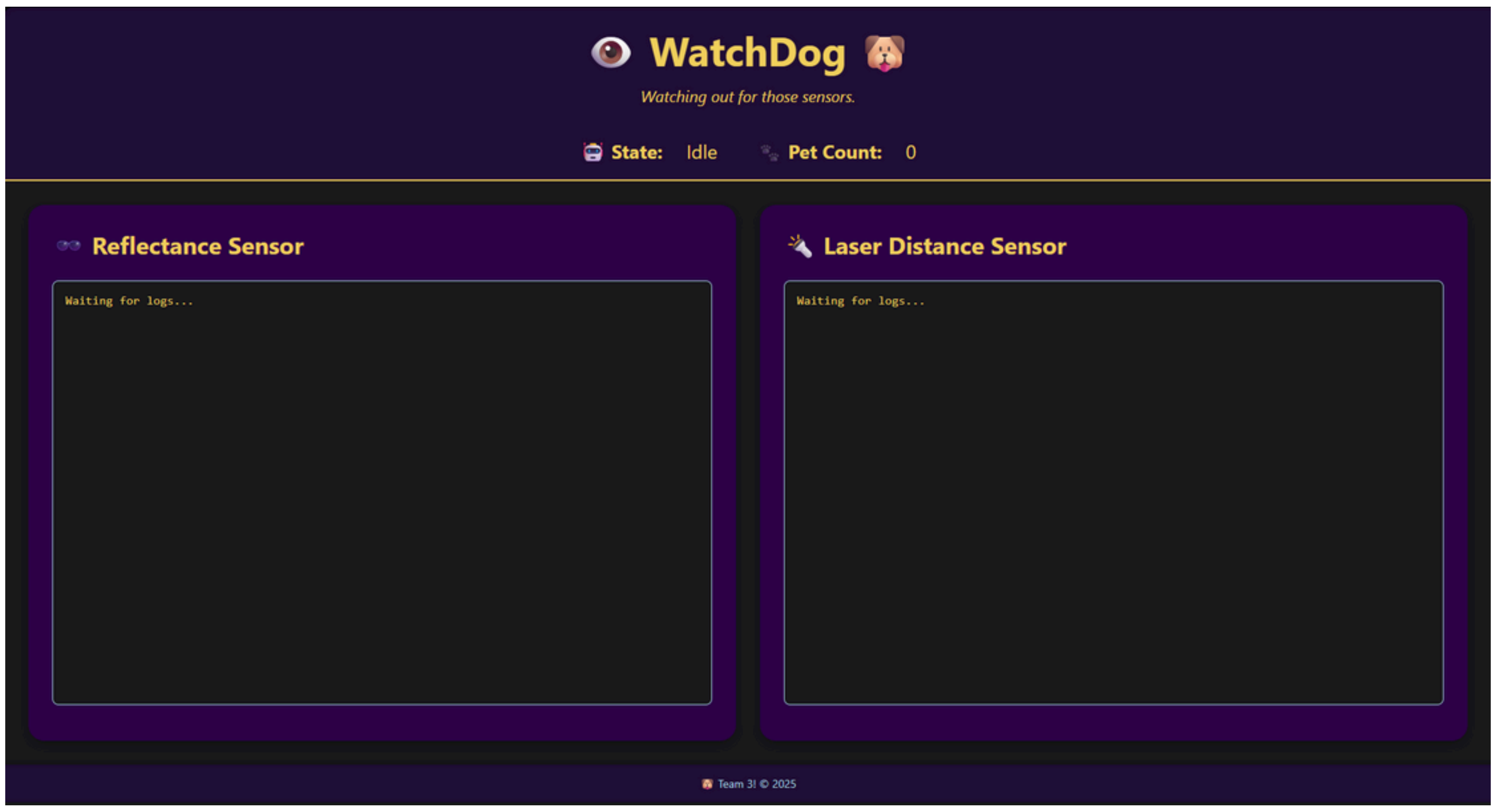
- Designed and prototyped a pulley-based lift system in Onshape CAD for transporting retrieved pets from ground level to an elevated zipline basket.
- Used a 76 RPM brushed DC motor paired with an H-bridge motor driver for directional control, interfaced with the ESP32 microcontroller running custom C++ firmware.
- Integrated the lift mechanism into the broader control system, synchronizing operation with other actuators and sensors via the robot's state machine.
- After initial testing, the lift was abandoned in favour of a safer, more reliable approach due to the risk of inconsistent deployment. This decision reflected a trade-off between speed and reliability, prioritizing competition consistency over maximizing potential scoring.



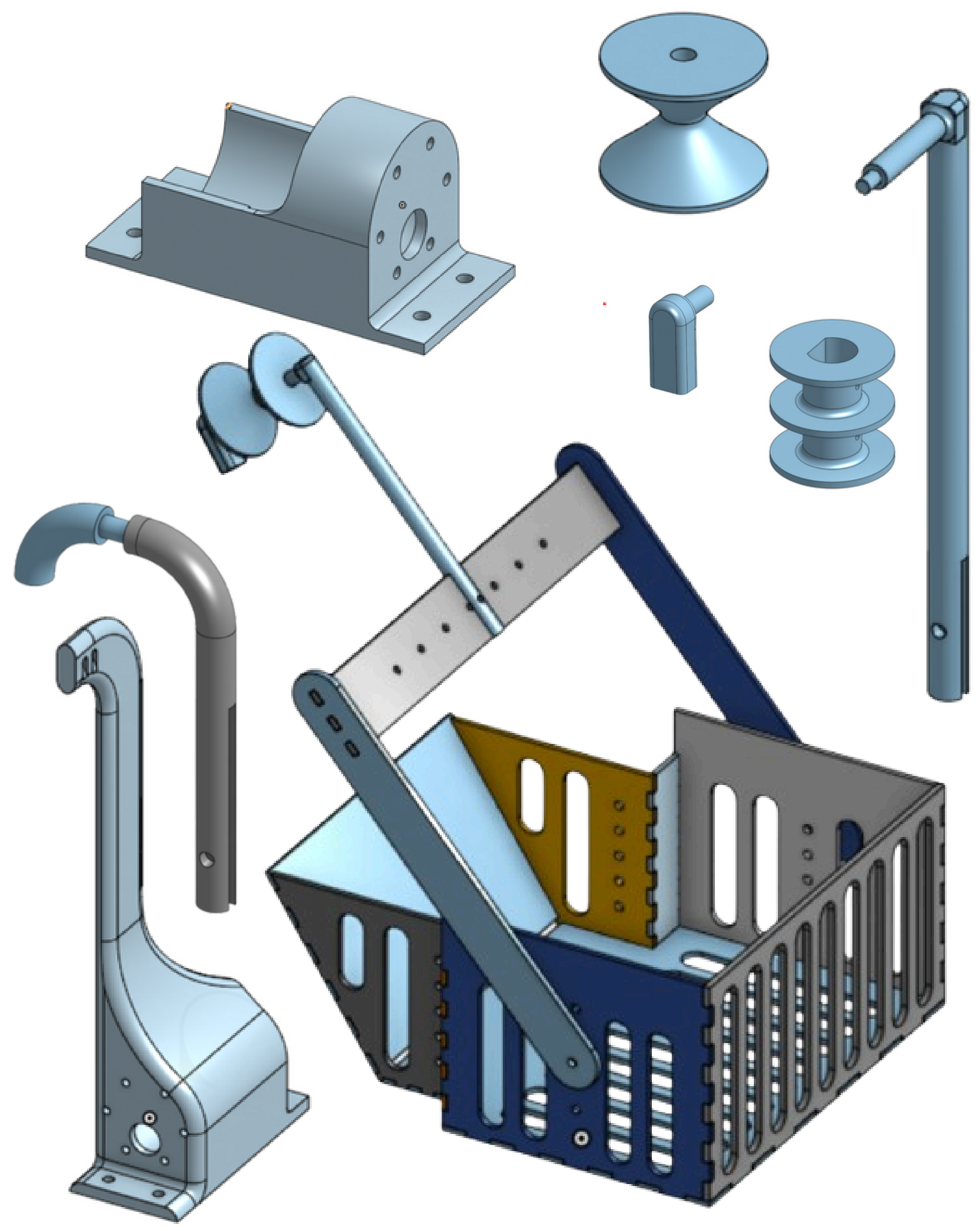


Logging Software

- Developed a lightweight logging and visualization system to collect and analyze sensor data, actuator states, and pet counts in real time, enabling rapid debugging and strategy optimization.
- Implemented the backend using Node.js and a JavaScript-based dashboard, leveraging multicore processing on the ESP32 to prevent data logging from interfering with control loop timing.
- Logged state transitions from the robot's finite state machine to diagnose failures and optimize traversal strategies.
- Integrated the logging framework tightly with the robot firmware, allowing engineers to observe live telemetry, replay competition runs, and improve recovery handling when unexpected events occurred.



Miscellaneous Components



Designed and fabricated dozens of custom structural components using Onshape CAD and in-house 3D printing to support the robot's mechanical and sensing subsystems.

Examples include:

- Sensor mounts for precise Hall effect sensor alignment and stability
- Motor mounts engineered for the drive and lift systems, designed to withstand torque loads while minimizing flex and vibration
- Pet basket hooks to securely latch the basket onto the zipline mechanism, preventing accidental drops during transport
- Custom spools for pulley-driven subsystems
- A lightweight pet basket optimized for durability, low mass, and secure holding during traversal

Iterated designs rapidly, validating fits, tolerances, and strength through physical prototyping and updating CAD models based on test results.

Optimized all printed components for a high strength-to-weight ratio, ensuring the robot stayed within strict competition mass limits while maintaining mechanical robustness and reliability.

Reflections and Future Improvements

In the future, I would invest more time in the integration phase. While all subsystems functioned individually, many didn't make it onto the competition-ready robot due to limited time for thorough de-risking. Additionally, I would optimize more for speed and weight. Our robot was large, heavy, and reliable — fitting the "tank" niche — but its size occasionally conflicted with rule compliance, and its slower speed rendered some planned strategies unviable.

However, this was the healthiest and most functional team I've been a part of. We consistently got enough sleep, fulfilled our roles effectively, and delivered a successful robot. I would continue prioritizing healthy team practices, including clear communication and establishing rules of engagement early in the project.

Links and Media

At 0:00, 0:38 and 2:14