Project Radian Robosub Technical Design Report

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1. Abstract

This is Project Radian Robosub's second year at competition. Our goal is to create a functional submarine that uses visual processing to complete tasks. We hope to qualify and complete a few of the basic maneuverability based tasks. Our team heavily utilizes rapid prototyping and 3D printing, and have designed our robot around simplicity and reliability.

2. Competition Strategy

A. General Approach

As a relatively small, new team consisting of primarily high school students, our primary objective is to create a functional underwater vehicle. While completing more advanced tasks such as picking up the garlic and the crucifix would be optimal, we do not believe it is a realistic goal for our team. Instead, we've opted to build a submarine with a focus on the essential components necessary for three-dimensional movement and environment detection in order to enter the undead realm and complete some additional tasks.

B. Scoring Strategy

Upon qualifying, our team plans on being successful in the following scorable events: Journey to the Undead Realm, Enter the Undead Realm, and Slay Vampires. These tasks are achievable within the capabilities of our submarine: visual detection and three dimensional maneuvering. With a vehicle as simple as our own, we chose to focus on the reliability of completing a few tasks instead of trading reliability for complexity. Our strategy is as follows.

Journey to the Undead Realm: The submarine will yaw clockwise or counter clockwise until the front facing camera detects the gate.
Enter Undead Realm (gate): The vehicle will recognize the gate after being trained with sample data and will maintain a heading toward the gate with onboard gyroscopes.
Follow the Path: Our forward facing camera will gimbal downwards and will detect the orange path markers and help orient the sub to the next scoring task.
Slay Vampires: We plan to have our sub hit any buoy as detected with the camera which will gimbal forward.

3. Vehicle Design

A. Hull and Frame

We chose our hull from Blue Robotics as to ensure that it was waterproof. Last year, we ran into difficulties in making our hull watertight, so this year we chose to purchase a commercially sold hull to ensure its watertightness.

Our frame was designed with simplicity in mind. In the shape of a rectangular prism, our frame was easily assembled with brackets and rivets. The design of the frame was also such that the hull is easily removable to access the electronics, while remaining extremely strong and stable.

B. Thrusters

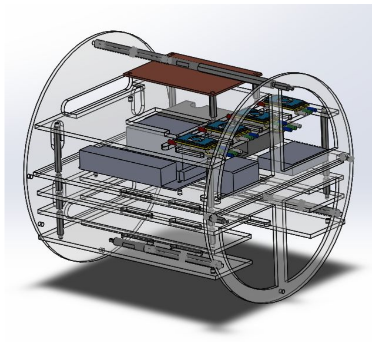
For our motors, we chose to use 430 kv brushless quadcopter motors used for medium-large quadcopters. As opposed to brushed motors, brushless motors have no exposed contacts, allowing us to avoid the issue of waterproofing our motors. For our propellers, we chose to use 3D-printed propellers sold by Blue Robotics after comparing the thrust produced by these propellers to those designed by our own team. Our team utilized plastic tubing to create shrouds for the motors, and we 3D-printed motor mounts. Our design choices allowed our thrusters to be both affordable and effective. The cost of each motor assembly was about $15 and produced about 3.5 pounds of thrust. This was measured with a thrust test jig that used weights and the force of gravity to oppose the strength of the thruster. The weight could then be measured, equivaling the thrust.

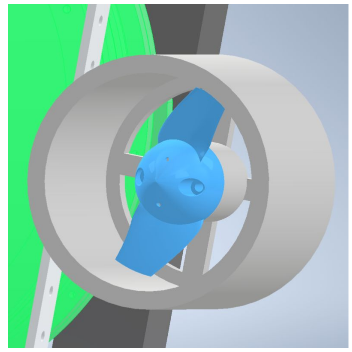
C. Camera

This year, our hull is transparent, allowing the camera to be mounted within the hull. Given our transparent hull, we are able to mount the cameras within the sub, one forward facing to target the gate, and the other downward facing to find path markers. Keeping all of our electronics in a single pressure hull like this allowed us to focus on waterproofing only one component, and has proven to be a much more effective strategy than last year.

D. CAD and 3D Printing

Our team used professional 3D modelling software and 3D printers to fabricate some of our more complex parts, such as our thruster mounting brackets, case mounts, and propellers. Each of these parts were designed, printed, tested, and reprinted multiple times before the final designs were completed. We were worried about the PLA material used in 3D printing degrading with exposure to water because of its biodegradability, but upon submerging a piece for several months with very little mass loss, we determined it was not an issue. We also avoided 3D printing any pieces that took significant structural loads, as last year we had issues with breaking and melting pieces. Instead, this method is only being used for complex shapes that take stress only from the thrusters and do not support the weight of the sub itself. The CAD of our electronics tray and thruster is shown.

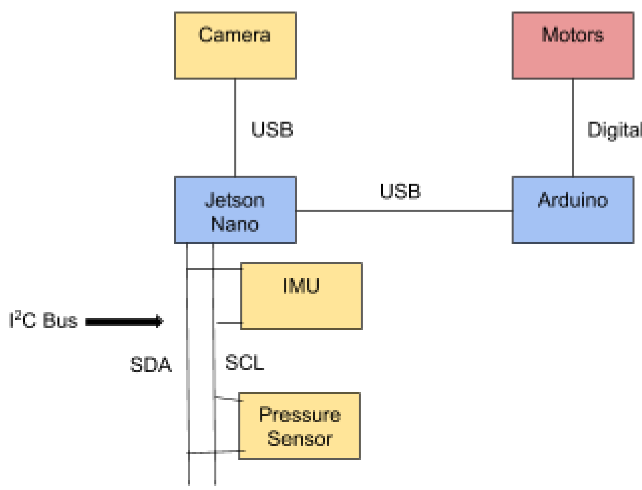




E. Electronics and Sensing

Our vehicle is powered by a single 6s 12C battery. A voltage converter is used to step the voltage of the battery down to the voltage necessary for our logic components. A diagram of our power flow is shown below.

Our vehicle utilizes the NVIDIA Jetson Nano to complete most of its processing. We chose to use the Jetson Nano for its additional processing power as last year a Raspberry Pi was insufficient for our needs. Connected to our Jetson Nano is an Arduino, a pressure sensor, and IMU, and a camera. Connected to the Arduino are the motors used in the thrusters. We chose to use an Arduino to control the motors because of Arduino's PWM support. Last year, we ran into



problems with PWM over the GPIO pins of the Raspberry Pi, so we chose to use an Arduino this year for our PWM needs, a system with which we are more familiar. A diagram of our data flow is shown below.

F. Software

The majority of our software is written in Python and Arduino C. The Jetson Nano handles our vision processing, sensor data, and our PID loop. All of the software on the Jetson Nano is written in Python. The Jetson Nano outputs serial data over a USB to the Arduino. The Arduino translates the serial data into motor values and sets the PWM for the motors. We are using Tensorflow and OpenCV to train our vehicle to recognize the gate to qualify for the semifinals.

4. Experimental Design

A. Motor and Propellers Testing

We determined which of the motors and propellers created the most thrust by creating a testing setup that would make it easy to compare the thrust of each design. It consisted of a thin wood plank which we secured to a table at one end and held the propeller in a bucket of water. When we ran power to the motors, it would push the end of the plank upward. We measured the distance that it rose and developed a propeller based on the designs that worked the best. This allowed us to choose the motor and propeller combination which produced the most thrust.

B. Electrical Connector and Case Testing

To test the watertightness of our hull and electrical connectors, we closed the hull and pumped air out of the hull via a one-way valve. We would periodically measure the pressure of the air inside the hull to determine if there were any leaks. We concluded that our case was airtight and hence watertight.

5. Acknowledgements

As a team we would like to thank our primary sponsor, Project Radian, for their support. They have given our team a makerspace to work in, monetary support, and mentoring from a previous team, Nautilus. Getting to the point we have, and learning what we have would have been impossible without this support. We would also like to thank Andrew Ross for his financial support and mentorship as well as Luke's on Front in Old Town, Temecula, and the Law Office of Julie Ann Baldwin, APC, for their monetary donations. Thank you.