UNDERWATER R.O.V: SELF STABILIZING, REAL TIME FEEDBACK PROVIDING, REMOTELY OPERATE UNDERWATER VEHICLE

Gregory McKinnon '18, Aaron Porter '18, Eduardo Murillo '18, Brayan Duarte '18
Faculty Advisor: Professor Kevin Huang

ABSTRACT

The goal of the project is to design an underwater ROV that has high maneuverability and ease of use all while being cost efficient. Our goals were to decrease the cost of these underwater R.O.Vs while still maintaining its full functionality, and implement the ability for the R.O.V to self stabilize while allowing 360° viewing via an onboard camera. Ideally, we would like to implement a combination of a accelerometer and gyroscope system (IMU) to stabilize the R.O.V, while allowing 360° viewing, which is a feature that most other designs lacked. If time allows we would like to try and implement the ability to hover in place as well, doing this would allow the R.O.V to remain at a fixed location while the user then controlled the camera to view their surroundings. In addition, designed and implemented an intuitive user control system that allows for easy maneuverability of the R.O.V. The user controlling the vehicle remotely shouldn't need extensive training to effectively operate the R.O.V. Knowing this, we plan to use a pre existing wired controller, more specifically an Xbox 360. This allowed us to focus less on the design of the controller and more on perfecting the responsiveness of the R.O.V to the user input with minimal delay.

BACKGROUND

Underwater R.O.Vs are not new technology, however most are large, industrial systems tethered to ships. Many of the current portable R.O.V designs are still in the prototype phase and most of these R.O.V designs are tailored for purely leisure. The current designs available tend to be expensive, prices ranging from $1,500 - $3,000. Designs like the Fathom one and Gladius Underwater Drone rely solely on motors to control how deep the R.O.V is, and provided no isolated motion control of the camera.
Ballast systems are most commonly seen in submarines. Submarine have ballast tanks that can be alternately filled with water or air, allowing it to control buoyancy. When the submarine is on the surface the ballast tanks are filled with air, lowering the submarines density and allowing it to float. Conversely, the ballast tanks are flooded with water, increasing the overall density, allowing the submarine to sink.

SYSTEM BREAKDOWN : ELECTRICAL

IMU Control system: An inertial navigation system (INS) was implemented. For our system, an inertial measurement unit (IMU) was used, as it is the smallest and most cost-efficient solution and it allows for the best interfacing with our Pi. The IMU provides feedback, giving and us our actual orientation. An error signal would be generated after comparing our desired orientation to the actual. Using this error, our system would produce an output to stabilize the R.O.V.

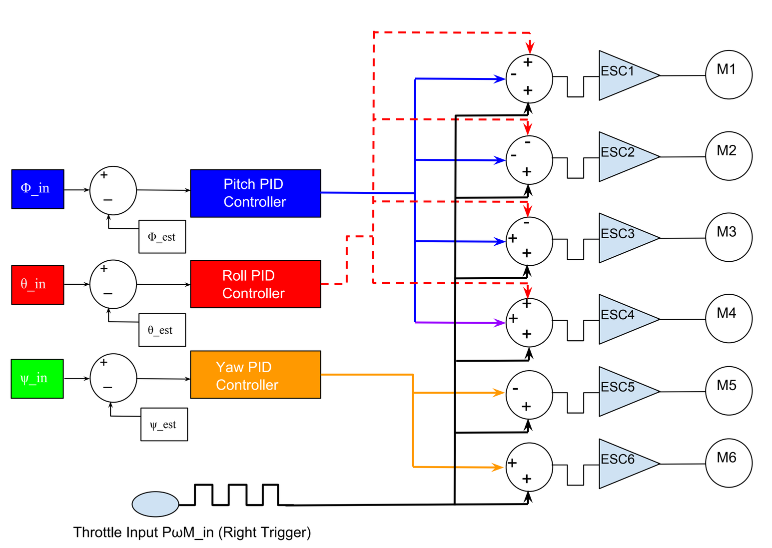

Figure 7. IMU control system block diagram

Raspberry Pi Interface: The processing board chosen was the Raspberry Pi Model 3B. For the purpose of this ROV, the programming language favored was Python, due to the API for the Xbox 360 controller natively running on Python and having a large amount of online support. The Raspberry Pi has an onboard GPU (Graphics Processing Unit) which was vital for displaying video feed from the camera. With the use of its built-in Wi-Fi, the Raspberry Pi would also allow for some future improvements, such as an un-tethered system, without rewiring.
Power Delivery System: The R.O.V.'s power delivery system includes an internal power source of two Li-Po batteries was used. We used two Gens Ace 11.1V, 1550mAh/17.2Wh batteries. According to preliminary calculations, running all six motors at once at full thrust (worst-case scenario) should provide a battery run-time of 7-8 minutes, which is respectable when compared to the run-time of commercial air drones.

THE FINAL DESIGN S.S. HOPE

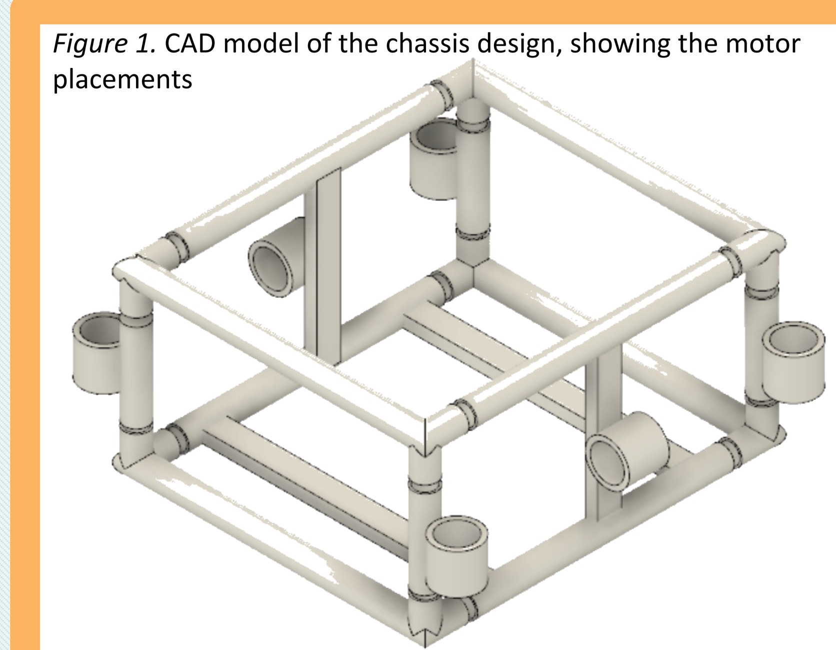

Figure 1. CAD model of the chassis design, showing the motor placements

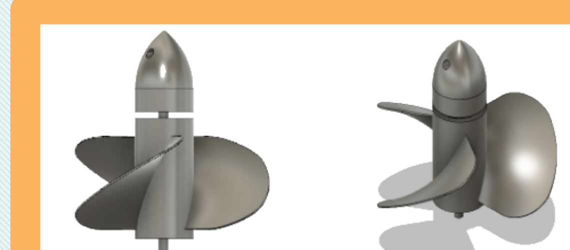

Figure 2. CAD model of the propellers designed for the Hobbyking ST3508 motors

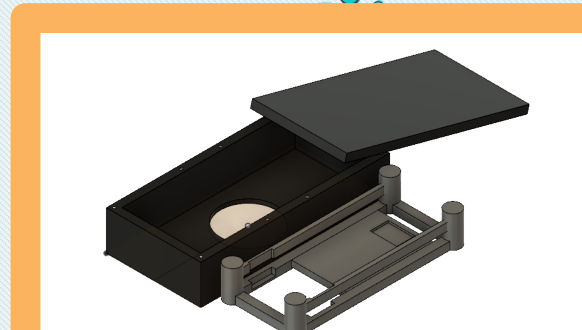

Figure 3. CAD model of the components box

Figure 4. R.O.V controller layout, using Xbox 360 remote

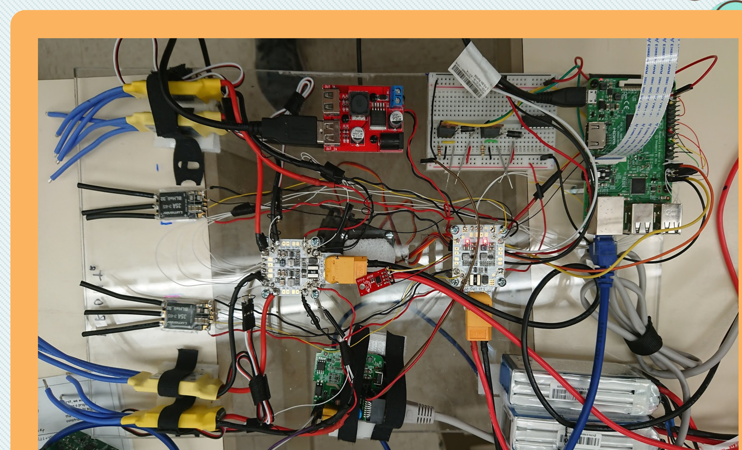

Figure 5. Electrical components laid out on acrylic board

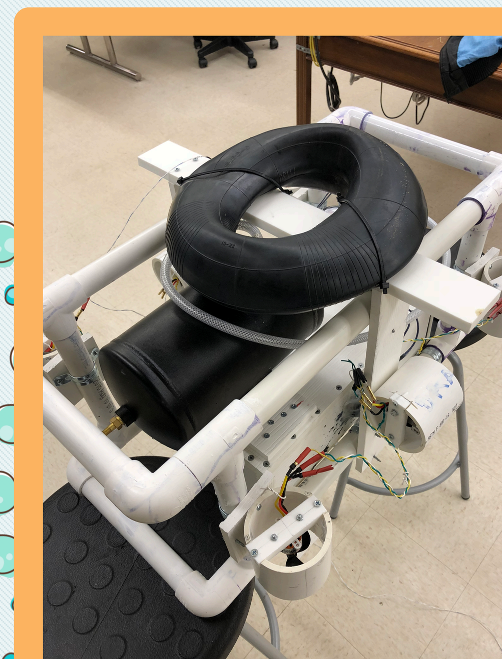

Figure 6. Completed R.O.V.

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SYSTEM BREAKDOWN : MECHANICAL

Ballast system: The ballast system is compressed air semi-closed loop system. Compressed air is held in a one gallon tank that is filled to approximately 100 psi. The tank is connected to a ball valve which will be used as a safety shut off, incase of valve or tank failure. A regulator immediately follows the valve, to bring the 100 psi from the tank down to 5-15 psi. After the regulator, the first solenoid is connected which is used to fill the ballast when opened, causing the R.O.V to float. A second solenoid opens, allowing air out of the ballast tank and causing the R.O.V to sink.
Motors and Props: The motors used in the system are brushless motors, due to their already waterproof state. Four Turnigy D2830 motors will be placed in each corner of the system, and two Hobbyking ST3508 motors will be placed on the side of the R.O.V. Four 3-Blade D52xD5x13 boat propellers were used for the Turnigy D2830. 3-Blade propellers for the Hobbyking ST3508 motors were designed as part of our engineering design aspect. CAD renders of the props and adapters are seen in figure
Chassis & Buoyancy: In order to remain neutrally buoyant and avoid moments being put on the R.O.V from unbalanced weights, a rectangular PVC chassis was designed. The chassis was built from 1" PVC pipe and 90° elbows. In the case of fresh water (the Trinity pool), calculations showed that ~ 6.5-7 lbs of ballast would need to be added to bring the chassis to a neutrally buoyant state.
Components Box & Waterproofing: The R.O.V electronics are located on board the system, allowing us to only need a single 2-wire tether for communication to the Pi. PVC decking material was chosen due to it being lightweight, affordable and non-porous. The material was cut to form a box of the following dimensions: 0.419 x 0.254 x 0.127 m . One of the sides of the box was designed to be able to be removed, for easy access to the inside electronics . A PVC screw cap fitting was cemented in place to allow access for the battery charging cables. Holes were drilled on both sides of the box, to allow a short piece of 1"-diameter PVC to be cemented on to the box. These holes allowed the wires to be routed from the motor, ballast and ethernet into the raspberry pi.

CONCLUSION + FUTURE WORK

Conclusion + Future Work: Due to waterproofing failures, the R.O.V was not submerged keeping in mind electrical safety concerns. Ideally, IP68 waterproof military connectors would have been used to route the necessary wires into the box. Due to financial and time restraints these IP68 military connectors were not able to be used. The different components were tested individually, and successfully integrated into one system controlled by the Xbox 360 remote. The ballast system design will allow better control of depth, as opposed to the commercially available designs. The incorporated camera system allows the user to pan and tilt the view with a great degree of freedom, without having to move the R.O.V. Because our system is based on an open source software, it will allow for future improvements and add-ons. Moving forward, we hope another senior capstone team can continue our work on the R.O.V. Immediate changes include complete waterproofing of the components box. Additionally, bulking up the features of the R.O.V to make it a more versatile system aside from leisure exploring is something to look into. For example adding a wi-fi buoy allowing it to be tether-less, or incorporating measurement tools like pH levels, or abnormalities in the water: such as high CO2 levels.

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