Unmanned Water Testing Vehicle
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Introduction
For our IGEM 230 Capstone Project, we have created the Unmanned Water Testing Vehicle. The goal of this project is to improve existing water testing procedures. Mining companies are currently required to deploy workers every two weeks to collect water quality data from tailings ponds. During these tests, all parts of the pond are considered and even the deepest parts of the ponds must be sampled for testing. Due to the number of tests required and the enormous size of tailing ponds, this operation can be rather time consuming.

Our team developed an autonomous watercraft that could be deployed to take water quality samples at various locations and depths with minimal user input, saving time and improving safety by removing the need for personnel to travel on the surface of tailing ponds.

After two rounds of C-sketches, we developed potential designs for each subsystem within the watercraft.

We used weighted decision matrices to objectify the advantages and disadvantages of each design. We made sure to slightly change the weighting of each criterion to ensure our decision was clearly the best option.

The various hull designs were evaluated based on performance in adverse conditions (42%), handling characteristics (26%), durability (17%), cost (9%), and weight (3%). The fiberglass catamaran outscored the rest of the options by a wide margin.

The propulsion systems were scored based on fault tolerance (36%), handling (34%), power draw (13%), cooling (9%), durability (5%), and cost (3%). Due to the double propellers’ high fault tolerance and the dual rudders’ reliability, the combination of the two scored the highest.

The water collection systems were evaluated on their fault tolerance (48%), number of samples (25%), volume of samples (13%), cost (5%), ease of replacement (4%), and power draw (4%). The pump scored the highest; however, after a consultation with Mr. Tedford from the Civil Engineering department, we decided to use “real-time” sensors and focus on pairing water quality data with its corresponding GPS location instead.

Design

Hull
Our design consists of a fiberglass-hulled catamaran, with a wooden deck. A metal plate mounted to the deck adds rigidity and prevents wood rot due to splash. The deck supports the GPS and a sensor winch mechanism on its surface while protecting navigation hardware and batteries mounted in the hulls. To support these components the boat is 80 cm long, 56 cm wide, and 21 cm tall. This design was chosen to support our target weight capacity and to provide maximal stability.

Navigation and Propulsion
Our watercraft is propelled by two water-cooled 2950kV outrunner brushless motors. These motors interface to separate electronic speed controllers which are connected to a flight controller. Each motor is attached to a two-bladed 3D printed 3.0cm in diameter propeller. Twin servo-actuated rudders provide additional attitude control. Both the motors and the rudders are connected to the flight controller. The steering and propulsion system is powered by two 1300mAh 11.1V LiPo batteries. The navigation system consists of a flight controller and associated sensors (GPS, Gyro, IMU) and a Raspberry Pi that receive radio signals from the operator and adjust the position of the rudders and the speed of the motors appropriately.

A microcontroller and motor driver are used to control the stepper controller. Both the motors and the associated sensors and hardware were performing properly.

Winch
The winch system consists of the following components: 1. Stepper motor 2. PVC arm 3. 3D printed spool 4. Sensor probe(s) and cabling 5. Vertical support and bearings

A microcontroller and motor driver are used to control the stepper motor, which then controls the direction the spool spins. The maximum depth is 50m, but due to the propellers’ high fault tolerance and the dual rudders’ reliability, the combination of the two scored the highest.

Assembly
We assembled our boat by standing both hulls upright and setting down the deck on top. On both the interior and outside sides of the deck, yellow putty was used to create a watertight seal. The motors were inserted into pre-drilled holes and sealed around the drivestail. To achieve reliable actuation, the servo rudders were installed on the back of the hull, close to the rudders.

The control boards, flight controller, motor systems and GPS are connected by wire through the tubing across the deck seen in Fig 4. Wiring through tubing provides waterproofing for critical electronics, and allows us to seamlessly connect engine systems from both hulls.

Hardware Block Diagram

Testing & Conclusions

Testing was performed in stages, starting with tests of each completed subsystem. Small scale prototypes of the hull were tested to verify buoyancy and weight capacity calculations, and our motors were tested to determine their total power output and to determine the correct prop size to be fitted. Once fabricated, each of our components was tested for function, floating characteristics, and then, once connected together, were tested for stability. The winch was tested before installation onto the deck, to ensure correct operation. Tests were also conducted to ensure our navigation sensors and hardware were performing properly.

After the completion of component and subsystem-level testing, we were ready for tests of the entire unit. We performed two tests of the watercraft under manual operation in the UBC fountain, to verify all systems were working together. We then conducted a final, fully autonomous test at Jericho Beach. This final test proved the autonomous capabilities of our boat, as well as its ability to handle difficult weather conditions.

While our testing did prove our project’s capabilities and potential, it also demonstrated that we still had areas of improvement, specifically in regards to the capacity and amperage of our onboard power supply and the waterproofing of our deck hatches.

Bibliography

Fig. 2 - An early CAD model of the Catamaran Hull and Deck

Fig. 3 - The vehicle, pre-installation of the winch and deck

Fig. 4 - The vehicle post manual operation test at the UBC fountain

Fig. 5 - The vessel post manual operation test at the UBC fountain