Unmanned Water Testing Vehicle

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Introduction

For our IGEN 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 tailings ponds.

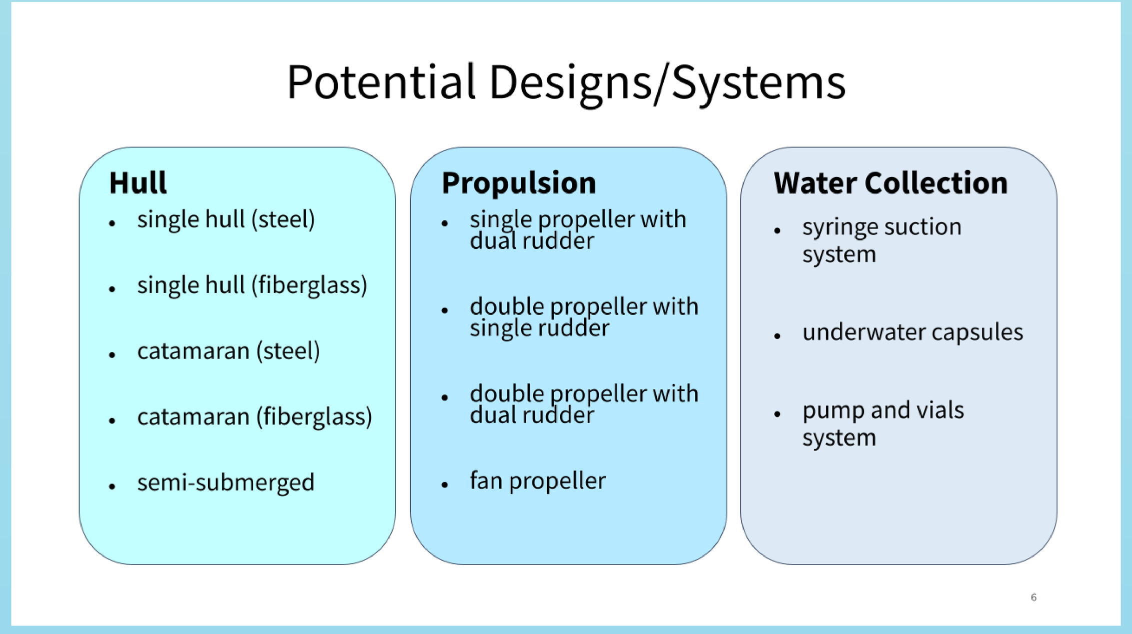

Fig. 1 - An overview of proposed designs for each watercraft subsystem

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. Ted 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.

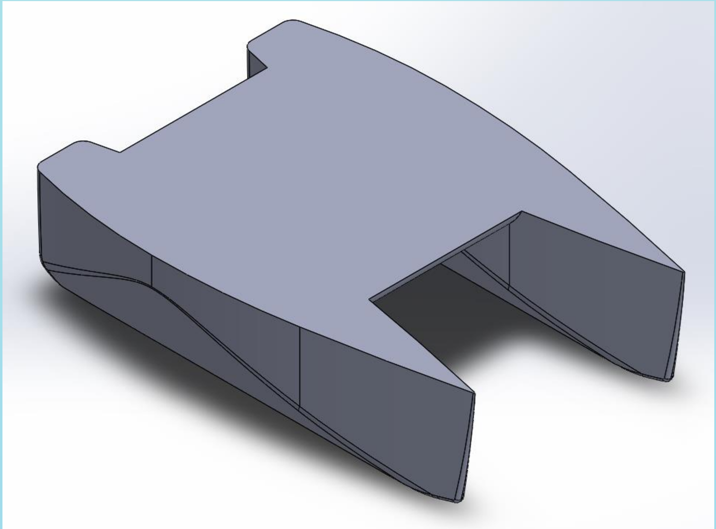

Fig. 2 - An early CAD model of the Catamaran Hull and Deck

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. The flight controller can autonomously move to a testing location and location stamp sensor readings.

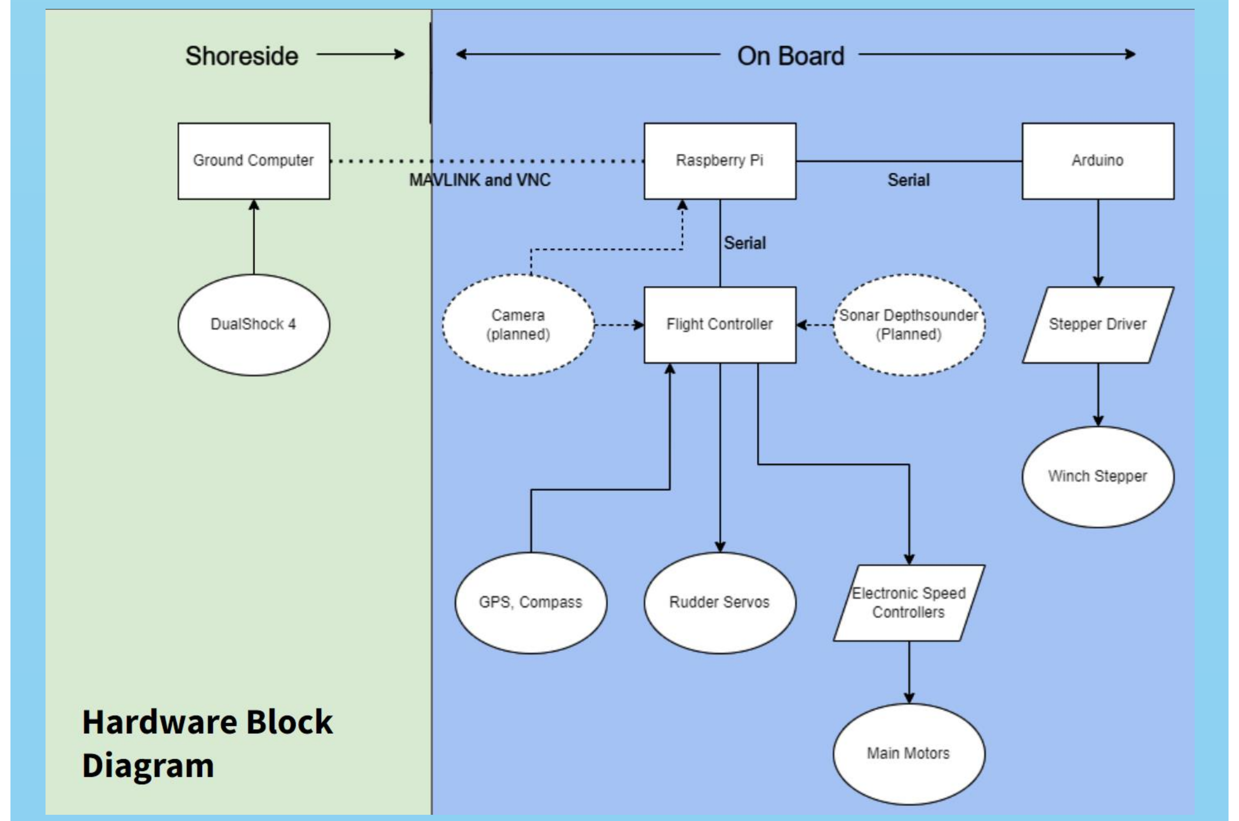

Fig. 3 - The interconnect block diagram for the watercraft's control hardware

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 driveshaft. 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.

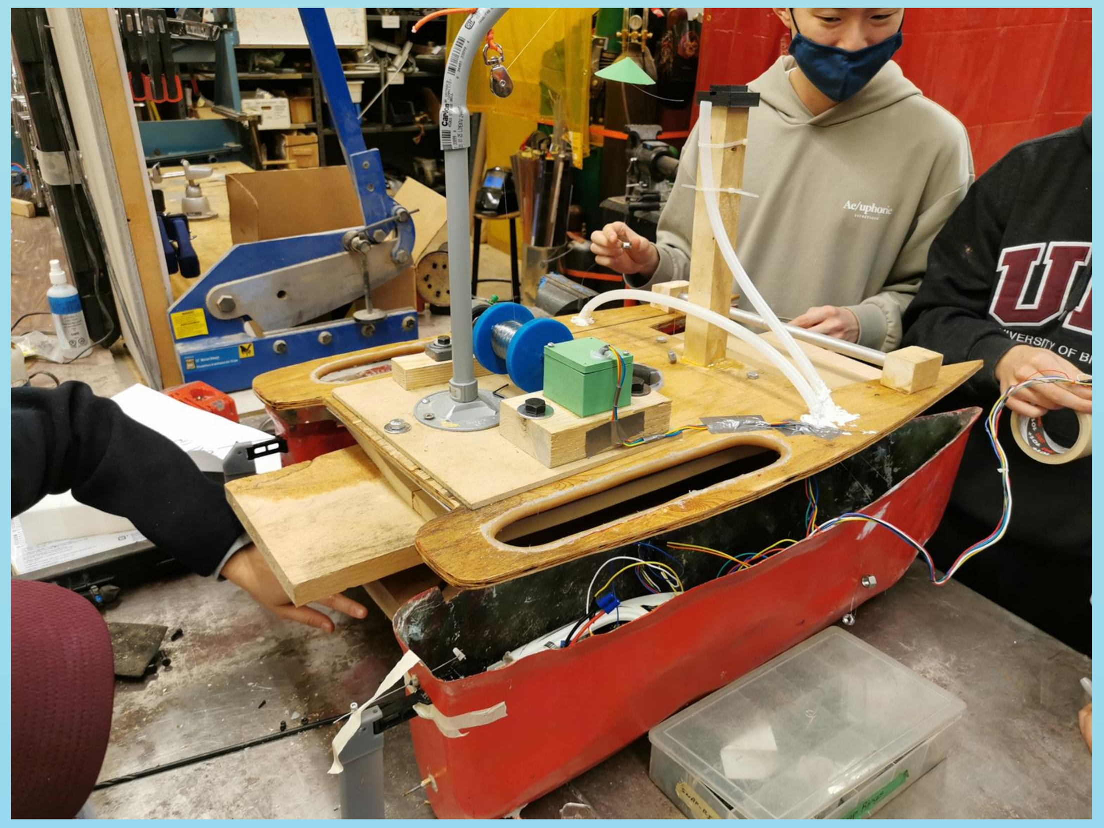

Fig. 4 - The vehicle, pre-installation of the winch and deck

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 could be configured to extend further depending on user needs. A placeholder sensor modelled after the RBRduo^3 or RBRconcerto^3 to the specifications of 355 by 63.25 mm with a dry weight of 1300 grams was used to test the winch. A conical guide was attached to our "sensor" to prevent the sensor from being caught on the deck and was set to sit part way through the deck to prevent swinging during boat movements.

This sensor was selected on the advice of Mr. Tedford, and allows user-configurable testing parameters, a high sampling rate, and time-accurate data logging, so that test data can be location tagged accurately.

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 hulls was tested for leaks and 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.

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

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

1. DC Motor Tutorial - Motor Calculations for Coreless Brush DC Motors. (n.d.). Faulhaber. Retrieved February 10, 2022, from https://www.faulhaber.com/en/support/technical-support/motors/tutorials/dc-motor-tutorial-dc-motor-calculation/
1. Lee, J. L. (2019). CIVL 215 Buoyancy [Slides]. Canvas. https://canvas.ubc.ca/courses/82947/files/19208213?module_item_id=4201981
1. RCExplained. (2020, June 30). Selecting a Brushless Motor, ESC, LiPo Battery and Prop for an RC Boat [Video]. YouTube. https://www.youtube.com/watch?v=2tuvoAfPMYU&list=LL&index=2&t=1277s&ab_channel=RCexplained
4. Rbrduo^3 & Rbrconcerto^3: C.T, C.T.D, C.T.D++: Ocean CTD. RBR. (2021, November 17). Retrieved March 17, 2022, from https://rbr-global.com/products/standard-loggers/rbrduo-ct?campaign=1484788070&content=549625591851&keyword=rbr+ctd