Design of "Bare Necessities": a boat to compete in the 2017 RoboBoat Competition

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***Abstract*— This year, 2017, is the Iowa Marine Autonomous Racing Club's (IMARC) first year competing in the RoboBoat competition. We have designed a built a boat named "Bare Necessities" to compete in the 2017 competition. Our boat consists of a trimaran hull with a twin propeller propulsion system. Because this is our first year competing in RoboBoat, the design strategy was one of simplicity. We attempted to find materials that were cost effective and easy to use wherever possible. Since Bare Necessities uses the Robot Operating System (ROS), we selected hardware that is designed to be ROS compatible. Bare Necessities uses LIDAR, sonar and computer vision to gather environmental data. Various libraries and algorithms are used to avoid obstacles, chart a path through the course and complete challenges.**

Fig. 1. Bare Necessities

I. Introduction

The Roboboat competition is an annual autonomous vehicle competition in which student teams design and build fully autonomous boats to compete against teams from around the world. This year's competition will be held at Reed Canal Park from June 20-25, 2017 in Daytona Beach, FL. During the competition, boats will complete the following challenges autonomously (Figure 2): an autonomous navigation check, follow the leader, obstacle avoidance (find the path), automated docking and a speed challenge. The team scoring the most points throughout the competition wins. This paper details our design process including design objectives, challenges, decisions and rationale for each of the major subsystems in our autonomous boat.

Our team - the Iowa Marine Autonomous Racing Club (IMARC) - was formed in the fall of 2016 and this year's competition will be our first. This paper details our design process, objectives and decisions over the past nine months.

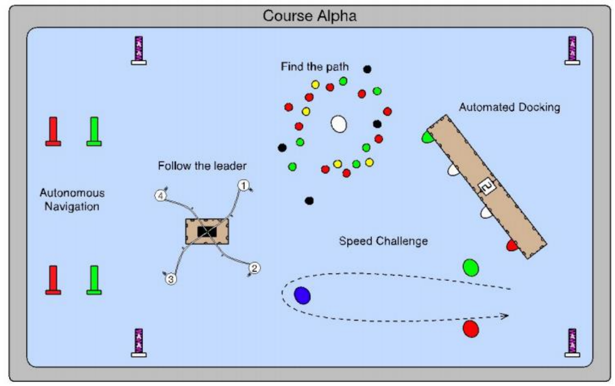

Fig 2. Course layout with labeled challenges.

II. Design Strategy

As mentioned before, Roboboat is a competition designed to test the capabilities of autonomous vehicles in various tasks within certain constraints. With this in mind, we gave the functionality of the system precedence. Due to the youth of our organization, we decided to go for a simpler approach, rather than an overly-ambitious one. The nature of our design was simplicity and functionality focused; allowing for greater potential in terms of tuning, improvements, and overall additions to the design. The nature of our design also allowed for more cost effective methodologies as well as the added benefit of using easily obtainable parts and materials. The benefits of this design style include the ability to focus on the crucial details of the competition, such as budget management, functionality, performance, accessibility, and safety. However, this decision impacts certain elements that would have improved performance for the competition, such as the speed and power efficiency. In order to understand how these design decisions impact the vehicle as a whole, it's important to understand how the systems of the boat work together.

In the spirit of simplicity and functionality, the design and construction process of Bare Necessities followed a three step process, with the goal of navigating autonomously. The first phase (Figure 3) consisted of a remote control boat.

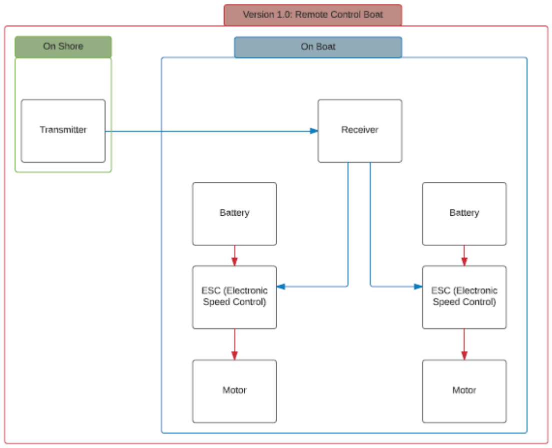

Fig. 3. Phase 1, Remote Control Boat

The goal of the second phase (Figure 4) was to provide the boat with a basic level of autonomy without having to start programming from the ground up. This functionality was provided by using a generic PixHawk autopilot board controlled by Mission Planner software.

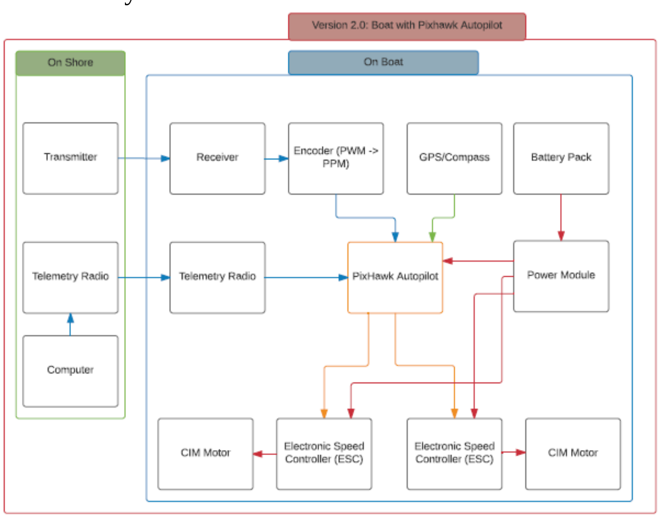

Fig. 4. Phase 2 of Bare Necessities

Phase three (Figure 5) aims to provide a level of autonomy sufficient to compete in the competition. This phase integrates additional sensors to allow for the boat to avoid obstacles. It also integrates additional hardware to allow for processing of the data from these sensors.

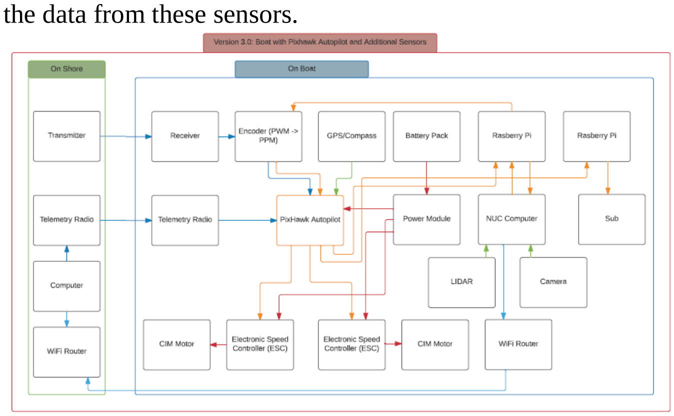

Fig. 5. Phase 3 of Bare Necessities

A. *Software*

The software aspect of the design can be broken down into two main pieces; the onshore and offshore systems. The onshore system is designed to relay instructions via Ethernet connection to an onboard computer, which processes data, makes decisions and communicates with other systems on the boat. In turn, the offshore computer relays the information back to the onshore team from the onboard equipment. With this data, it would also be possible to recreate and analyze the results of the run for the future through software, such as Gazebo, a robot simulation software. As previously mentioned, the offshore system waits for basic instructions from the onshore team. Once it receives the task, the boat's computer relays specified algorithmic instructions to the individual systems in order to accomplish the task. These instructions will be provided by using the Robot Operating System (ROS) to send and receive commands data and commands. The system works by taking in real-time data from the sensory information on board, and combining it with the user/task request in order to accomplish each mission. Integrating these numerous elements together creates the overall autonomous system. The boat will function autonomously at the competition.

B. *Propulsion System*

A twin propeller propulsion system was selected for this design. This design is simple yet effective. To maneuver using a twin propulsion system, propellers simply need to be spun at different rates. This design also eliminated the complexity of designing and implementing a rudder system. For the propulsion system, two CIM motors were selected. Through intuition and the analyzing of torque outputs, the CIM motors were found to be sufficient for the purposes of the competition. See Figure 6 for the motor testing apparatus. Motor shafts are connected to the driveshaft using flexible rubber couplers (rubber hose). The couplers compensate for misalignments and damp some of the vibrations in the system. The end of the shaft was threaded to allow for the propeller to be secured onto the shaft using nuts. The driveshaft passes through the outer pontoons within a PVC pipe, held by 3D printed bushings. The PVC pipe is held in place with spray foam insulation.

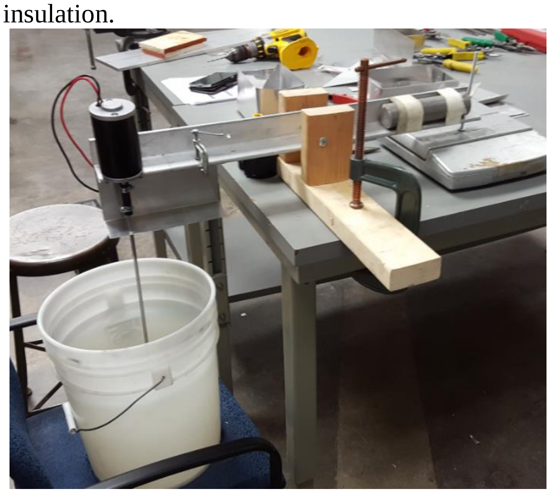
Fig. 6 CIM Motor Testing

C. Hardware

A deep cycle marine battery is used to power the boat. The battery was selected because it was readily available and would have more than enough power to run the boat throughout the duration of the competition. A LIDAR is used to create a map of the course from the boats point of view. See figure seven. Three sonars are used to identify and avoid objects immediately near the boat. A camera is used to identify colors, numbers and for other challenges requiring computer vision.

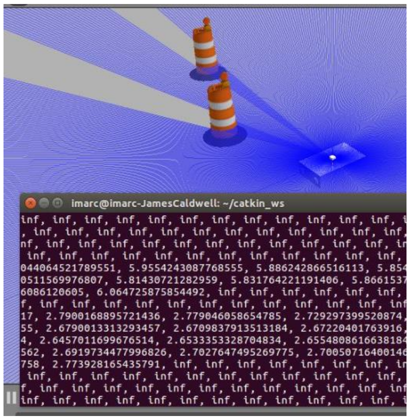

Fig. 7. Lidar Simulation

D. Hull Design

The emphasis this year being IMARC's first design was simplicity. After researching previous boats that had done well in the competition, a catamaran style design was chosen. Catamarans are stable and resist roll and pitch effectively. Additionally, the catamaran provides an excellent surface on which a platform can be mounted.

Early hull designs were tested using REX simulation software. See Figure 8.

Fig. 8 REX Simulation of Hull

After in-water testing, the team realized that an additional pontoon was needed. This changed the design into a trimaran.

Manufacturing was an area that most of the current IMARC members were inexperienced in so the team kept the design simple. For the competition, the pontoons were made out of extruded polystyrene glued together, then shaped using a band saw. The hulls have angled holes that run through the center of the hull which provide an area for the propeller shafts to run through.

A deck was made out of ¼" plywood. The platform has additional spacers which are ¼ inch pieces of plywood with the same length and dimensions as the top of the hull. These spaces are glued in and contain bolts for which the deck platform can be bolted to the hulls with. This platform provides an excellent surface to place components. The deck is reinforced with 2x4s on the bottom of the deck.

III. Experimental Results and Testing

Bare Necessities was tested at a hotel pool and at Terry Trueblood Park where there is a small lake which can easily be used for testing. Since our club does not have the resources necessary to make an obstacle course in the water, the boat was also simulated using ROS using Gazebo - a robot simulation software.

IV. Acknowledgements

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- University of Iowa Electrical and Computer Engineering Department
- University of Iowa Chemical and Biochemical Engineering Department
- University of Iowa Civil Engineering Department

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