Holonomic Drive Autonomous Surface Vehicle

University of Louisiana at Lafayette
Ragin' Cajuns

Christian Gary
Mechanical Engineering

Kaleb Gautreaux
Mechanical Engineering

Luke Matt
Mechanical Engineering

Grant Bellard
Mechanical Engineering

Dr. Joshua Vaughan, Ph.D.
Project Advisor/ Associate Professor
Mechanical Engineering

Abstract

The boat entered for the RoboBoat Competition by the University of Louisiana at Lafayette team implements creative methods and effective tactics to achieve the set goals in each challenge. An important feature of this boat is its ability to move with holonomic motion. The thrusters are placed in an X-configuration, allowing it to have pure sway and yaw motion. With the X-configuration of the thrusters and the hull made of a Styrofoam core and fiberglass outer layers, the boat's robust nature and manuverability will provide the capability to perform well in the 2019 RoboBoat Competition.

Competition Strategy

The overall goal of the Ragin' Cajuns RoboBoat Team was to keep the main functionality of the Autonomous Surface Craft simplistic and efficient. As a result, maneuverability and weight were driving factors in the boat's design. Likewise, due to this being the first time the University of Louisiana at Lafayette has participated in RoboNation's RoboBoat Competition, physical design and fabrication of the boat were prioritized over other aspects of the vehicle.

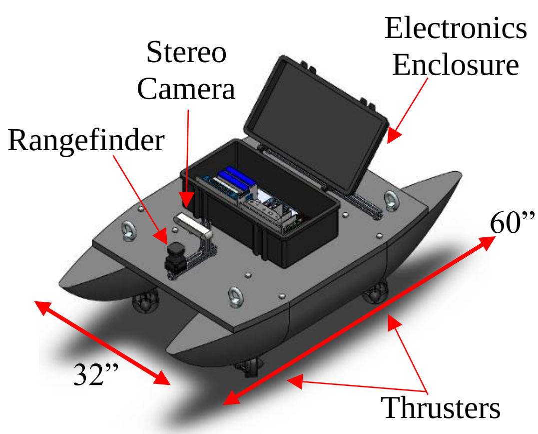

Figure 1: Final ASV Design

A CAD rendering of the entry is shown in Figure 1. It shows many of the features of the design, such as the thrusters, rangefinder, stereo camera, and the enclosure. With the focus of the design project being on the shape of the hull and the propulsion configuration for high maneuverability, some challenges in the RoboBoat Competition will be more important for the team as compared to others. A unique point of this project is the absence of an Unmanned Aerial Vehicle (UAV). The boat's participation in the Raise the Flag challenge was sacrificed to focus on essential features of the boat, such as its mobility. The Speed, Docking, and Find the Path challenges are prioritized as a result.

Thrust manipulation for surge, sway, and yaw will be the main focuses in navigating through the obstacles of each challenge. Pure surge, sway, and yaw movement will be utilized in the boat's navigation. Through experimentation, this is possible and will provide an advantage to the Ragin' Cajuns RoboBoat team.

Design Creativity

To maximize the maneuverability of the boat, the propulsion system has four thrusters in an X-configuration, as shown in Figure 2. This allows the boat to move with holonomic motion. If the desired direction of the design is in the positive sway direction, because all the thrusters positioned with the same angle magnitude, the positive and negative surge thrust counter-act allowing for movement only in the positive sway direction. The thrusters are also adjustable, allowing varying proportions to surge, sway, and yaw. With this desired motion, the stability and multi-directional operation were the main factors in deciding the hull shape, in addition to keeping a simplistic method of manufacture.

The boat was designed as a catamaran, as shown in Figure 3, with two double-ended

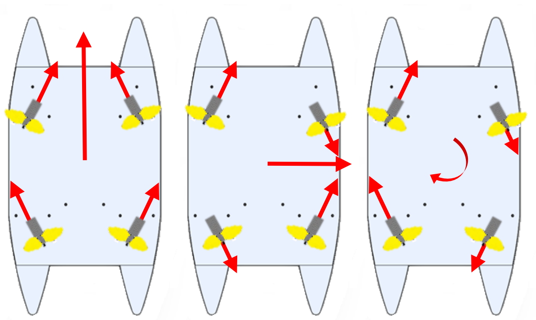

Figure 2: Diagram of Thrusters in X-Configuration

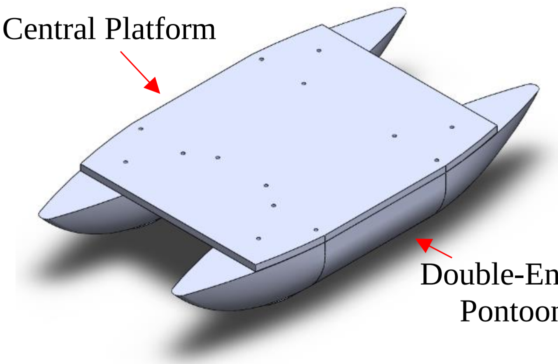

Figure 3: Catamaran/Hull Design

pontoons with slightly sharp cutwaters to allow for better surge, sway, and yaw movements. The pontoons are connected by the central platform, where the electronics enclosure is located. The pontoons were shaped to mimic standard hull coefficients used in the commercial boating industry.

The boat was designed to be easily manufactured, while also having a high buoyancy and having high maneuverability. Table 1 shows the standard hull coefficients of commercial boats compared to the hull coefficients of this boat [1]. The prismatic, midship, and water plane coefficients describe how well a boat cuts through water, how rounded the bottom is, and the ratio of the area of the water-plane to the area of the circumscribing rectangle, respectively.

Table 1: Hull Coefficient Analysis

Calculated Hull Coefficients	
Parameter	**Equation**
Prismatic Coefficient	0.721
Midship Coefficient	0.659
Water plane Coefficient	0.807
Standard Hull Coefficients	
Parameter	**Equation**
Prismatic Coefficient	0.590
Midship Coefficient	0.785
Water plane Coefficient	0.710

Table 2: Buoyancy Analysis

Buoyancy	
Parameter	**Value**
Weight of Boat (lbs)	55.6
Total Volume of Submerged Hull (ft^3)	0.892
Volume of Submerged Pontoon (ft^3)	0.446

Table 2 shows the buoyancy analysis of the boat. To find the buoyancy the weight and submerged volume of each pontoon were calculated to account for how deep the boat will be in the water. The boat will have less than a cubic foot of total material in the water, allowing for more weight to be added to the boat if needed.

In consideration of simplicity and buoyancy, the boat was formed from a Styrofoam core and multiple layers of fiberglass cloth combined with various epoxies. Figure 4 shows pieces of the pontoon as foam cutouts. The foam core was shaped from 1-inch thick foam planes, which were glued and sanded to match the desired curvatures. The layering process of the fiberglass and epoxy is shown in Figure 5. The layering process consists of two layers of fiberglass and epoxy for the strength, a layer fairing compound to smooth and level the fiberglass and epoxy, and a coat of spray paint for aesthetics.

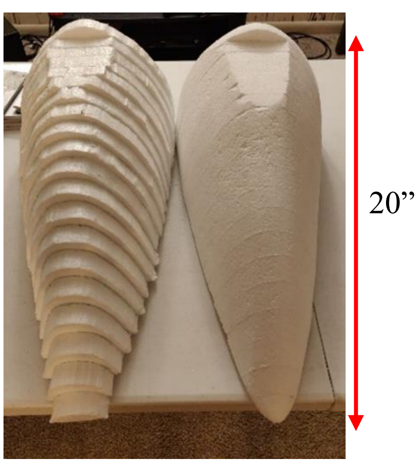

Figure 4: Pontoon Foam Cutouts

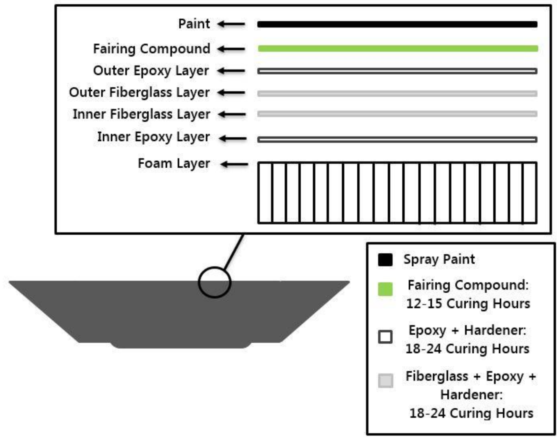

Figure 5: Layering Process

Due to the low weight of foam and fiberglass, as well as the robust nature of the fiberglass-epoxy composite, the boat's buoyancy is overwhelmingly high, reducing the drag on the boat, therefore, allowing for high speeds and quick turning to be attained. Addition of extraneous components will not be an issue with the buoyancy of this boat.

The hydrophones that will be implemented for this competition will be deployable from a dipping arm off the stern side of the central platform, where they will be separated about a foot apart from each other. Once the boat maps out the dock using the camera and rangefinder, it will adjust to face perpendicular to the dock for a short time while it reads the ping. Once the boat is fully adjusted, the docking of the boat will commence.

Experimental Results

The ROS Framework was used to program the entry due to the access to open source material. Most of the high-level code for the ASV is taken from the University of Louisiana at Lafayette's RobotX boat and modified to work with this design's sensor configuration, which simplifies the coding process and saves time. Another benefit of ROS is that nodes can be on separate hardware and still be able to communicate with each other through a network This allows for the TX2's, the Raspberry Pi, and the base computer to be connected through the same framework, publishing and subscribing to topics. The TX2s are used to take in sensor information, process images and sounds, and plan a path. The Raspberry Pi is used to control less taxing functions like the thrusters, the mode indicator, and the e-kill switch. A sample operation diagram of the boat is shown in Figures 6 and 7. This diagram shows how the ASV communicates with the base computer when it is in teleoperation mode.

Through the ROS Framework, an environment was used to test the coding. Testing in this environment allowed bugs to be found and fixed. Whenever the bugs were fixed, the boat was placed in water and tested in a pool. The boat was proven to have holonomic motion through remote access.

Acknowledgments

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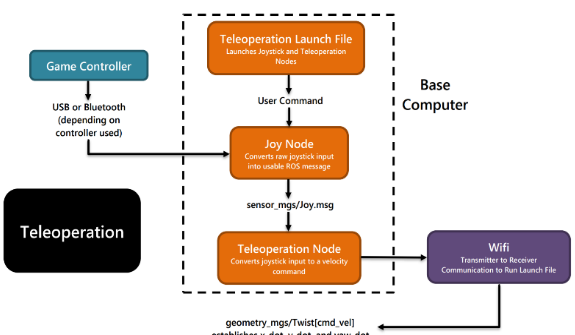

Figure 6: Base Operation Diagram

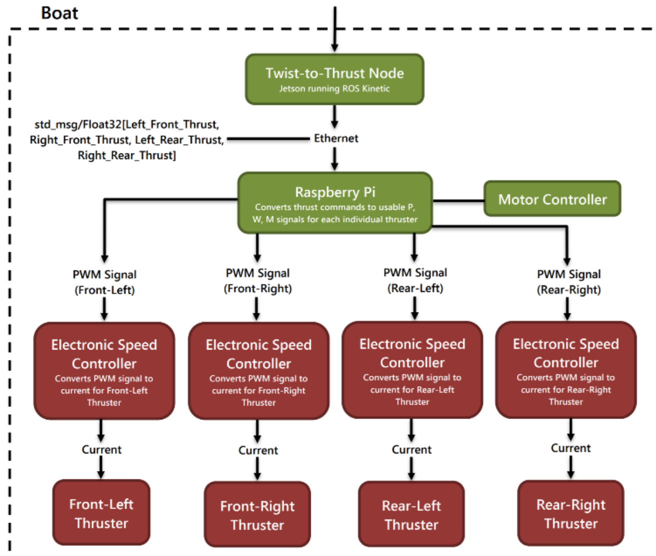

Figure 7: Operation Diagram of Boat

References

[1] Catamaransite.com. "Catamaran Design Formulas." Catamaran Design, www.catamaransite.com/catamaran_hull_design_formulas.html.

Appendix A: Component Specifications

System	Model/Type	Vendor	Specs	Cost ($)
ASV Hull Form/Platform	Fiberglass	Total Boat	6 Oz. Fiberglass Cloth (38"x 360")	56.01
	Epoxies and Other Compounds	Total Boat	Traditional Epoxy Kit (152 oz.) and Epoxy Fairing Compound (2 Qt.)	173.98
	Shaping (Foam)	Amazon	Insulation Foam Blocks (4 Panels)	118.76
	Control Box	Monoprice	Weatherproof Hard Case- 12182	89.99
Waterproof Connectors				
Propulsion	T-200 Thrusters	Blue Robotics		676.00
	Basic Electronic Speed Controllers	Blue Robotics		100.00
Power System	Batteries (6)	Turnigy	4 Turnigy (5200mAh 4S Li-Po)	215.84
		Floureon	2 Floureon (4500 mAh 3S Li-Po)	66.58 (Pre-Owned)
Motor Controllers	Raspberry Pi (2)	Raspberry Pi	Raspberry Pi 3 Model B+	35.00
CPU	Jetson TX2 (2)	NVIDIA	Module and Carrier Boards	1259.98 (Pre-Owned)
GPS	Ultimate GPS Breakout (746)	Adafruit		39.95 (Pre-Owned)
Lidar	Scanning Rangefinder (UTM-30LX-EW)	Hokuyo		4900.00 (Pre-Owned)
Teleoperation	Wireless N Access Point (TL-WA901ND)	TP-Link		37.99 (Pre-Owned)
Compass				
Intertial Measurement Unit (IMU)	UM6	CH Robotics	r2 Ultra-Miniature Orientation Sensor, Serial and USB Expansion Boards	1260.00 (Pre-Owned)
Doppler Velocity Logger (DVL)				
Camera	Stereo Camera	Zed		449.00 (Pre-Owned)
Hydrophones	H2C Hydrophone	Aquarian Audio		338.00 (Pre-Owned)
	USB Audio Interface	Focusrite	Scarlett 2i2	159.99 (Pre-Owned)