Technical Design Report- RoboBoat 2021
Military Technical College- MW

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1. *Abstract:*

In this report, we are going to present our vehicle design and strategies to accomplish competition tasks. This design aims to overcome previous vehicle design problems and improve overall performance based on real-time experimental results obtained throughout months of practice and tests. Generally, our team tends to achieve competition tasks using simple and efficient ideas.

2. *Competition strategy:*

To guarantee the best results, we should improve the overall performance in all fields. Therefore, in the beginning, we have to define system requirements and the compatible design that focuses on achieving the best performance in all competition tasks.

2.1 Hull design:

Our hull design oriented by our predefined targets and requirements for this year competition, which are:

1- Minimum weight.
2- Minimum drag.
3- High stability.
4- High maneuverability.
5- Safety factor for buoyance force and design strength.

To minimize vehicle weight while keeping a strong structure, the vehicle is mainly fabricated of fiberglass. Our hull design is based on NPL Series for high-speed vessels. Besides that, we have customized the vehicle to have a suitable buoyancy within the defined dimension limits. Simulations experiments are performed to estimate the expected water resistance, stability, and maneuverability ranges.

For the manufacturing process, we decide to split the boat into suitable sections as a guide for outer curves. Then, we aligned all sections and collected them to get the designed shape.

Fig.1,2 & 3- Manufacturing Process

2.2 Quadcopter:

For object delivery task, we decide to complete it using a quadcopter that picks up objects from target area corners for delivering them to the target area center. Our Quadcopter is mainly made of Carbon fiber sheets connected together using epoxy and Snap fits. Our design intent ensures high stability and maneuverability with minimum weight. In addition, the Quadcopter airframe design aims to minimize air resistance that is achieved using simulations on the outer cover of the quadcopter to choose its most efficient shape.

Fig.4 & 5- Quadcopter full assembly

2.3 Object detection and recognition:

In order to guide the boat to move among the buoys autonomously without hitting them, we need a system able to identify the buoys and generate a map to navigate through them. Therefore, we use both LIDAR and camera to facilitate the detection and recognition process of the obstacles. The used camera sensor provides a suitable way to differentiate between buoys based on both shape and color.

2.4 Positioning:

We propose a navigation system to localize the boat relative to the obstacles. The system collects data from several sensors and combines them to get results as accurately as possible. We placed RTK and IMU on our boat. Once the onboard computer is turned on, it has its location and waypoint to control the thruster's power and move the boat to the destination point using differential thrust.

2.5 Mission tasks:

2.5.1 Mandatory Navigation Challenge

This task is very important, as it must be completed before attempting any other tasks on the competition course.

Using the onboard navigation system, the vehicle localizes itself perpendicularly to the middle of the entering gate then moves in a straight line until reaching the exit gate and going through it.

2.5.2 Obstacles Channel

Object detection, color recognition, and navigation systems are all necessary to position the vehicle and start the challenge. A proposed image processing algorithm is used to detect both red and green buoys to guide the vehicle through them. When the algorithm detects yellow buoys, the vehicle will avoid them to continue its path.

2.5.3 Obstacle Field

To find an opening gate in the field of obstacles. The vehicle will identify and detect the pill buoy's position using the proposed image-processing algorithm and navigation system. The vehicle will cross through the buoys to the pill buoy then transit around it until the vehicle crosses the approach path. Then, the vehicle looks for the nearest way to get out through a suitably selected gap.

2.5.4 Acoustic Docking

In the beginning, the boat will move perpendicular to the docking bays while searching for maximum signal intensity source. Once, the vehicle localizes the signal source. It moves to the bay of maximum signal intensity and exits the bay.

2.5.5 Object Delivery

To accomplish this task, we design a quadcopter with suitable dimensions, shapes, and systems.

The quadcopter will deploy from the vehicle's surface and use the navigation system to go to the target area corners. At each corner, it will identify the object. Then, using a quadcopter gripping mechanism, it picks up the object and delivers the object to the center of the target area.

2.5.6 Speed Gate

Similar to the obstacles Challenge, detection process and color recognition are necessary to position the vehicle and start the challenge. An image processing algorithm is used to detect red and green buoys to pass between them with maximum velocity until detecting the marked buoy to rotate around it. Finally, the vehicle will exit through the starting buoys.

2.5.7 Return to Dock

Using both navigation and image processing systems, the vehicle will decide a suitable path starting from its current position to the launching point. This path will be chosen to not interfere with courses and avoid all obstacles to ensure the vehicle's safe return.

3. *Design creativity:*

3.1 Mechanical design:

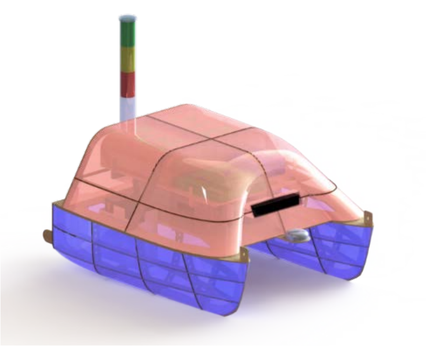

Fig.6- UMV's full assembly

The main contribution of our mechanical creativity lies in our design characteristics and its production process. Taking into consideration that the competition contains many steering-based tasks compared to high-speed tasks, we make our design leaning to stability and maneuverability more than having high speed. Therefore, we go along with a catamaran design for high stability and a different propulsion system for tight turnings.

By manufacturing our Vehicle with fiberglass, we ensure minimum weight with suitable strength. In addition, we manage to maintain suitable stability and maneuverability by carefully choosing our vehicles' design parameters. Simulations are performed to check the vehicle's performance.

3.2 Software

We used LabVIEW for control due to its simplicity and creativity.

We integrated our ROS work with LabVIEW by sending only command velocity to the controller. We have tried to keep it as simple as possible. Our design is modular and simple for modification.

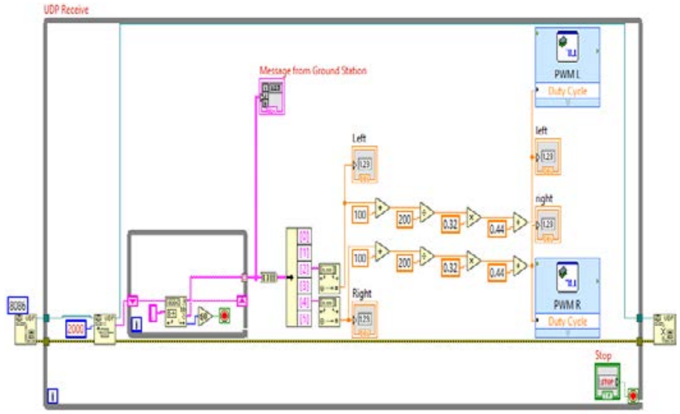

Fig.7- communication between ROS & LabVIEW

We used MyRio as a controller, where it is compatible with LabVIEW besides its quick response compared with other microcontrollers. We use ROS to send command velocity to MyRio as shown in (Fig.7). Hence, it sends PWM signals out to the thrusters.

We use a PID system (Fig.8) after using UDP communication between ROS & LabVIEW.

We use very accurate sensors to localize our boat in the field. Sensors such as VectorNav 200 & GNSS Module.

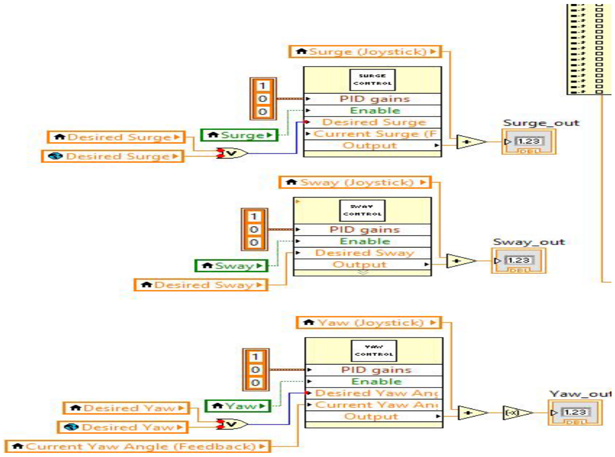

Fig.8-PID control

4. Experimental Results:

4.1 Testing with simulations:

4.1.1 *Vehicle's Performance:*

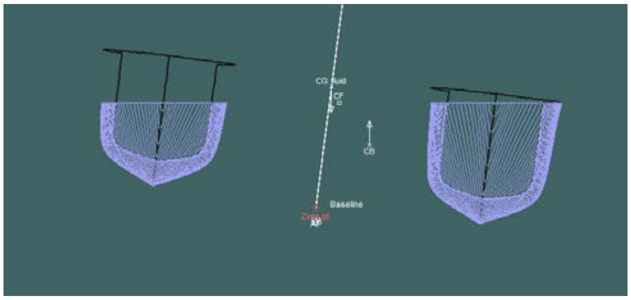

Fig.9- Vehicle's stability test

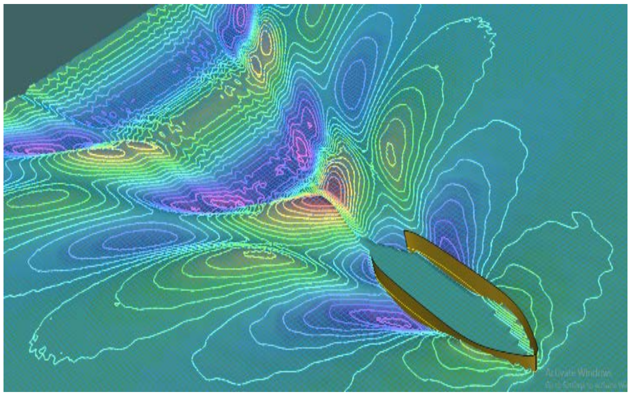

Fig. 10- Water resistance test

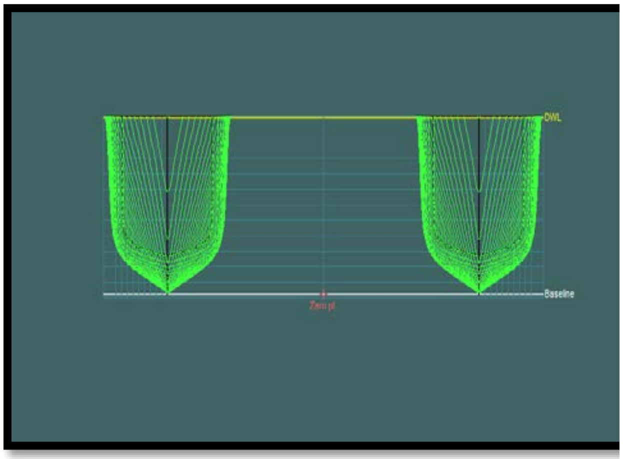

Fig.11- Body plane lines

4.1.2 Autonomous Tasks with Gazebo:

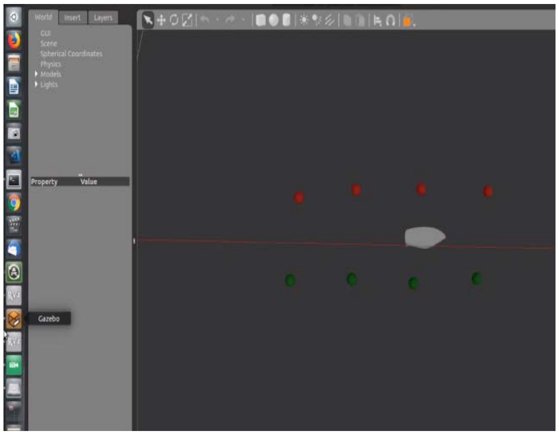

Fig.12-Obstacles channel

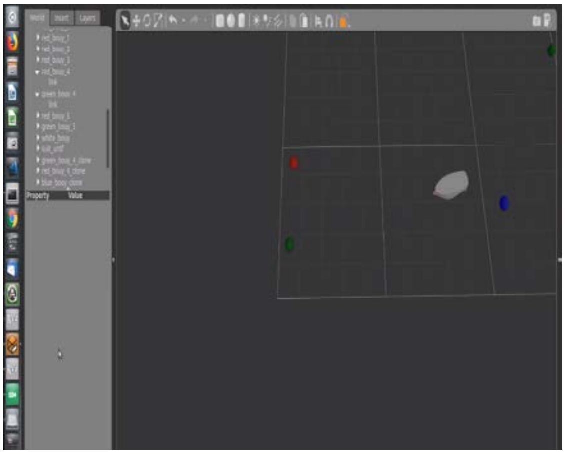

Fig.13-Speed gate

4.2 Practical tests:

Fig.14- Vehicles buoyancy test

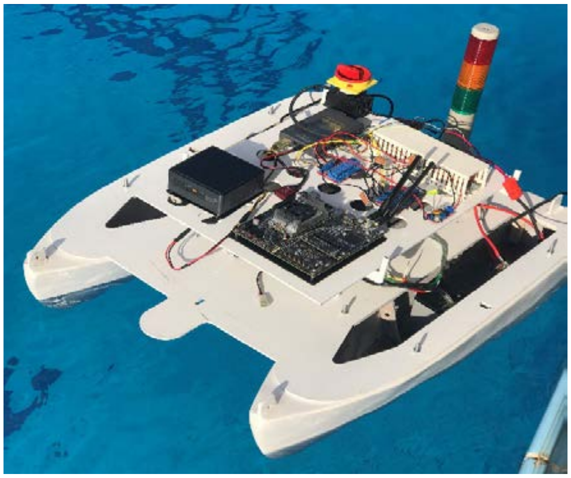

Fig.15- Autonomous tasks test

5. Acknowledgment:

The Idea of creating MW team is to be able to participate in this competition. It would not become a fact without all the generous contributions and support of our college. It helped us by providing funds and necessary equipment. Really, they are one of the main reasons for what we have reached so far.

Thank you for your support

6. References:

❖ K. Nonami, F. Kendoul, S. Suzuki, W. Wang, D. Nakazawa," Autonomous Flying Robots", Springer Japan, (2010).

❖ Lentin Joseph, "Mastering ROS for Robotics Programming", Packt Publishing; 2nd Revised edition, (2018).

❖ Ghazi, S.BariKonstantin, and I.Matveev, " Hydrodynamic modeling of planning catamarans with symmetric hulls", Ocean Engineering, Volume 115, 15 March 2016, Pages 60-66.

Ship Mechanics and Electrical System

Component	Vendor	Model/Type	Specification	Cost
ASV Hull Form/Platform		Catamaran		
Propulsion (2 Motor)	Blue robotics	T200 Thrusters	Each: Thrust 5.1 kgf and Power 350 watts	$ 585.00
Power System (2 Batteries)	Amazon	Lead Acid	432 Wh	
Motor Control (microcontroller)	National Instruments	NI-MyRio	-	$ 535.00
Computer (GCS)	Amazon	-	Intel NUC NUC8i7BEH Mini PC	$ 850.00
Communication (Router)	Amazon	TP-Link AC2300 Smart Wi-Fi	-	$ 240.00
LIDAR 360	Robot shop	RPLIDAR A2M8 360° Laser Scanner	-	$ 300.00
IMU	Vector-Nav	vn-100 kit	-	$ 800.00
Hydrophone	Aquarian audio	H2A HYDROPHONE	-	$ 170.00
RC Transmitter and receivers		Futaba 8JA	8-Channel 2.4GHz	$ 400.00
Camera	Amazon	Logitech c930e	-	$ 82.00
RTK	Amazon	Emlid RS+ GNSS	-	$ 800.00