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UPRM Roboboat Team: RUM-BA

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***Abstract*— This paper describes in detail the design and manufacturing process of RUM-BA, the UPRM Roboboat Team vehicle for the competition. Since this is the first time competing the team applied a wide variety of creative solutions in order to design the most optimal vehicle. These solutions include the use of PVC as the material to build the boat's flat hull structure. The thrusters integrated to the vehicle are the T200. An adaptation of an FrSky transmitter/receiver set to a Turnigy 9X RC controller was made. The recreation of objects detected in a virtual map generated by the LIDAR will be used alongside ultrasonic sensors and a dual lens camera with Stereo Depth will be used to navigate through the tasks. The system architecture consists of 3 main modules: Mapper, Mission Planner and Controller. Our base communication system and software architecture is designed using ROS. The vision system consists of a dual camera that is used to apply a SLAM with Stereo Depth, and a clustering algorithm (HDBScan) to identify objects. The embedded system consists of a Beagle Bone Blue controller that has Ardupilot connected to a TX2 to take decision and commands. Due to lack of time and resources the team had to choose three out of the six tasks to complete. These tasks are autonomous navigation, speed challenge, and find the path.**

Keywords—Autonomous, ASV, ROS, LIDAR, Ardupilot.

I. Competition Strategy

Since it is the first year of the UPRM Roboboat Team participating in the competition, it was planned that the ASV would complete four of the six tasks. We would start with autonomous navigation, then speed challenge, find the path, and raise the flag for last since it requires a drone deployment. Considering that only partial autonomy was achieved we currently plan on setting up the position and orientation of the ASV manually and then starting the corresponding task mission when the desired position is reached. After doing further considerations, having time restrains and lack of resources, we decided to focus on three tasks out of the six tasks, leaving the raise the flag task for next year's competition. For this year competition, the target is to complete the following tasks flawlessly and acquire the most points possible for each.

A. *Autonomous Navigation*

Since this is the mandatory task, it will be completed at the start of the run. RUM-BA will determine the position of the buoys, that will be the starting point, using the Lidar and the camera. The ASV will go from one waypoint to the other using YOLO to detect the next gateway buoys and Stereo Depth in combination with the LIDAR to obtain a corresponding midpoint waypoint to pass through them. In case it gets near a buoy that is out of its Field of View (FOV), the ultrasonic sensors will help in the redirecting of the vehicle, avoiding the object.

B. *Speed Challenge*

Similar to Autonomous Navigation, using the camera and the LIDAR, RUM-BA will determine the position of the starting gateway. After going through, the vehicle will use 75% of the thrust to reach the blue buoy as fast as possible without losing vision of it. Then it will go around it and come back to the starting waypoint. With this, we hope to achieve the fastest time for the task and acquire more points for its execution.

C. *Find the Path*

For this task, RUM-BA will rely on the virtual map, generated using data from the camera and the LIDAR, and finally the ultrasonic sensors, positioned in five locations around the vehicle. This combination performs obstacle avoidance considering all the buoys detected and allows safe navigation through the empty paths of the course.

II. Design Creativity

Some creative solutions were applied to the project to improve precision and performance. From the start, the manufacturing of the boat was complex due to our personal experience and available materials. Due to its low density and high strength, PVC board was the right material to build the boat's structure. Then the adaptation of an FrSky transmitter/receiver set to a Turnigy 9X RC controller was another interesting solution to extend the range of our radio communication. Also, simplifying the position of objects by using a dual lens camera that is capable of Stereo Depth. Another one is the use of Ultrasonic sensors for avoidance of objects out of the generated map and field of vision of the LIDAR and camera. Finally, the recreation of the objects detected in a virtual map is very useful to have at hand reliable data that can be reused throughout all the competition days when stored.

A. *Vehicle Design*

Because we are a starting team, we decided to design and manufacture a flat hull vehicle because of its simplicity and stability, using PVC sheets. The flat hull is a planning one used mostly on calm waters, which is the expected behavior of the competition pond.

Figure 1: Hull assembly process.

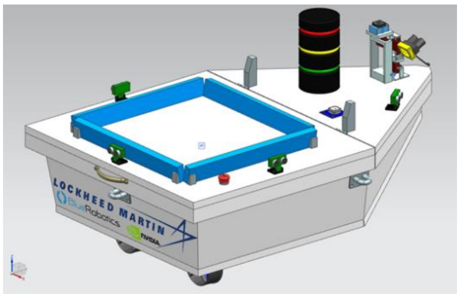

Figure 2: NX CAD of the vehicle original design.

All the components will be settled on the inside on top of a platform (Figure 3). This was added to raise all the components for, in case water entered the ASV, they do not become submerged/in contact with such creating a short circuit.

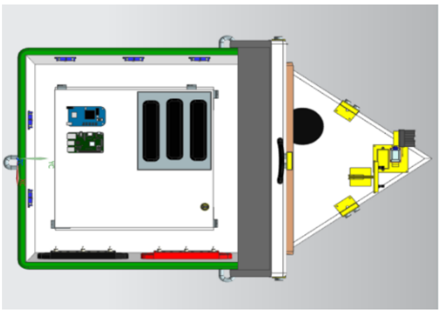

Figure 3: Top view of vehicle with the inside platform perspective.

After doing some testing, we saw that the bow was coming up when cruising at higher speeds. This became an issue since the camera would lose visibility and, because the thrusters where so close to the waterline, they would start to take in air. To correct this issue, extensions where added to the propulsion. This will help submerge the T200 thrusters deeper in the water and avoid the nose of the ASV to raise.

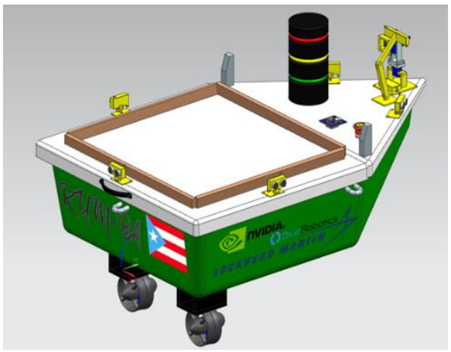

Figure 4: NX CAD of the vehicle final design.

B. *Electrical*

The electrical subsystem is composed of all the electrical connections inside the boat. The principal connections are for the three batteries that are used for the full functioning of the boat. They are located over a platform for the safety of the components if any water gets inside the boat. The batteries are connected to a switch for the protection of any malfunction before connecting them to the components.

Voltage regulator are vital components for all connections. The regulators help protect all items of receiving an exceed of power. From this point, all the power through all the boat to microprocessors, ultrasonic, thrusters, and the light tower. Every component has its own voltage regulator.

C. *System*

The system architecture consists of 3 main modules: Mapper, Mission Planner and Controller. The information fed into these are provided by the Vision, Ultrasonic, GPS and IMU modules that will use sensor data to correspondingly inform positioning and distance of the objects detected. Objects detected are given to the Mapper to be added into a Map that is later used by the Mission Planner to give corresponding control commands to the Controller.

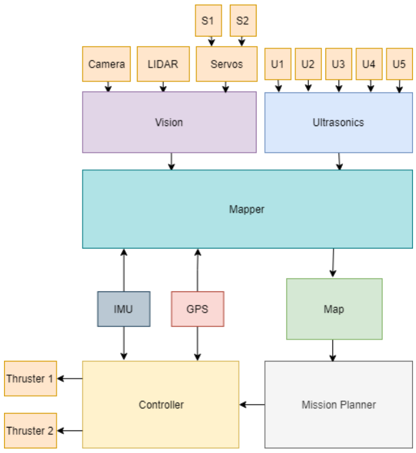

Figure 5: System architecture.

This architecture is then translated in terms of ROS, our base communication system.

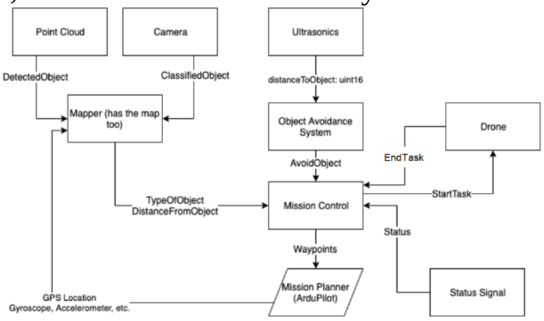

Figure 6: ROS communication diagram.

D. *Vision*

The vision system consists of a dual camera that is used to apply a SLAM with Stereo Depth to generate point cloud data from the visible surroundings. A clustering algorithm, HDBScan, is then used to identify object due to a high point density in a specific location. These detected objects are passed to the mapper with the corresponding location to position them in a virtual map appropriately. A similar object detector is performed with the LIDAR sensor where it uses the distance and servo positions to obtain a point cloud. HDBScan is also applied to this point cloud to properly identify objects that are later passed to and it only needs clustering because it already identifies the point.

E. *Embedded*

The embedded system consists of a Beagle Bone Blue controller that has Ardupilot installed to be capable of autonomously move the boat to the different positions required. A TX2 is connected to it to take all the decisions necessary and to then give the correct commands to the Beagle Bone Blue to acquire the correct positions. An Arduino is connected to the Beagle Bone Blue and to all the ultrasonic sensors to implement a layer of object avoidance. An Arduino Nano is connected to the TX2 to add the LIDAR functionality with the servos to the system. Also connected to the Beagle Bone Blue there is the GPS to know the positions of the boat and the radio receiver to receive manual inputs from a radio controller.

III. Experimental Results

Due to time restrictions and pool schedules, our tests were limited and mostly for critical functions. Initially when the boat was manufactured a weight and buoyancy test was performed by adding 100 pounds of weight into the boat and it successfully withheld and floated. Later, when the thrusters were mounted, we tested them in both directions and what was the maximum and minimum PWM they were able to support. Seeing that they had more than the necessary thrust output, it was time to proceed to manually navigate the boat. A considerable lift of the bow was observed, and it was due to the thrusters taking air due to their proximity to the surface. An extension was implemented to fix this. In parallel software tests were occurring and it started with testing YOLOv3 in the board it was going to run, which was Raspberry Pi 3 (RPi3) now. It was difficult for the RPi3 to run this but later we were able to acquire a NVIDIA TX2 board that is capable of this. Then to train it for the real competition objects we had to collect data from the forums and then perform data augmentation techniques to train a model that would recognize these objects. These models were tested, and they were not identifying objects properly. To fix these reduced the labels for object identification and decided to further identify a generic buoy by color.

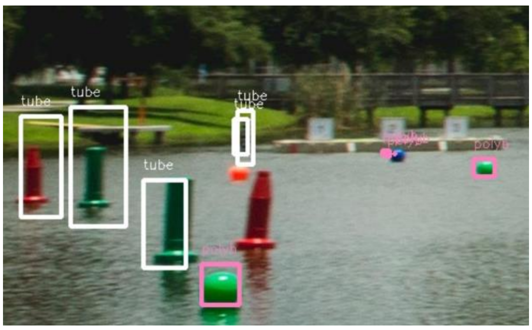

Figure 7: Object Identification using YOLOv3.

When the system was further developed a GPS, test came into place and we noticed how sensible it is to other electrical components and the walls of different types of materials. A high position in the boat was required for proper function of the GPS sensor. Alongside this after the Beagle Bone Blue was calibrated gyroscope tests were performed and the horizon was identified in the mission planner accordingly to reality. Later, an RC Controller was bought and configured for long range with a module swap from a DJT to a FRskY transmitter/receiver set. Range was tested in the pools at it responded perfectly at a considerable distance. In relation to ROS, the communication of both systems was tested through a talker/listener script that sent a hello world message to each other through their local IP address using the TX2 as the ROS master. Last tests were related to autonomous movements and we had issues because it seems that we had a misconnection in the thrusters that caused it to move to another position and very quickly. Ardupilot parameters related to orientation and speed were verified and fixed.

Acknowledgment

The UPRM Roboboat Team would like to thank first the Association of Females in Mechanical Engineering and our professor advisor, Dr. Ivan Baiges, which gave this project the opportunity and the resources for its genesis within the University of Puerto Rico at Mayaguez. Secondly, we are extremely thankful to our sponsors, Lockheed Martin, NVIDIA, AMGEN, Blue Robotics, the Engineering Faculty, and the University of Puerto Rico at Mayaguez. Without their financial support, we would not have been able to achieve the different milestones to become a new coming team within the competition. Lastly, we thank the university community and our families for supporting each team member on the different activities executed throughout the semesters leading to the competition.

References

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Appendix A: Component Specification

Component	**Vendor**	**Model/Type**	**Specs**	**Cost (if new)**
		Hardware		
PVC sheet	Home Depot	Modified	4’x8’	$89
14.8V, 10Ah Batteries	Hobbyking	Turnigy Graphene	Capacity: **10000mAh** Voltage: **4S1P / 4 Cell / 14.8V** Discharge: **15C Constant / 30C Burst** Weight: **936g (including wire, plug & case)** Dimensions: **168x69x40mm** Balance Plug: **JST-XH** Discharge Plug: **XT90**	$100 each
Jetson TX2	Nvidia	TX2		$600
Thrusters T200	Blue Robotics	T200	**Maximum Forward Thrust @ 16V** 5.1 kg f 11.2 lb f **Maximum Reverse Thrust @ 16V** 4.1 kg f 9.0 lb f **Maximum Forward Thrust @ 12V** 3.55 kg f 7.8 lb f **Maximum Reverse Thrust @ 12V** 3.0 kg f 6.6 lb f **Rotational Speed** 300-3800 rev/min	$169 each
Ultrasonic	Amazon	HC-SR04	Working Voltage: DC 5V Working Current: 15mA Working Frequency: 40Hz Max Range: 4m Min Range: 2cm Measuring Angle: 15 degree Trigger Input Signal: 10µS TTL pulse Echo Output Signal Input TTL lever signal and the range in proportion Dimension 45 * 20 * 15mm	$9.78
Voltage Regulators	Amazon	eBoot	Input: DC 3 V to 40 V (input voltage must be 1.5 V higher than the output voltage, no boost) Output: DC 1.5 V to 35 V voltage is continuously adjustable, maximum output current is 3 A	$10.95
Voltage Regulator for TX2	Amazon	Solu		$9.59

Voltage Regulator for Beaglebone Blue	Amazon	DROK		$9.00
Beaglebone Blue	Beagleboard	Beaglebone Blue	AM335x 1GHz ARM® Cortex-A8 processor 512MB DDR3 RAM 4GB 8-bit eMMC flash storage Integrated power management 2×32-bit 200-MHz programmable real-time units (PRUs) NEON floating-point accelerator ARM Cortex-M3 USB2 client for power & communications, USB2 host	$82
GPS	FPVDrone	Ublox M8N	Ublox Neo-M8N module • Industry leading –167 dBm navigation sensitivity • Navigation update rate up to 10 Hz • Cold starts: 26s • LNA MAX2659ELT+ • 25 x 25 x 4 mm ceramic patch antenna • Rechargeable 3V lithium backup battery • Low noise 3.3V regulator • Power and fix indicator LEDs • Protective case • 30cm Pixhawk2.4 compatible 6-pin and APM compatible 5-pin 2 types cable included • Diameter 60mm total size, 32 grams with case.	$27.89
Camera	SVPRO	SV-960P2CAM-V90	1.3MegaPixels,Max. Resolution 2560(H)X960(V) Sensor 1/3 inch OV9750 Pixel Size 4860μm x 3660 μm Resolution & frame MJPEG：2560X960@ 60fps/2560X720@60fps /1280X480@60fps /640X240@60fps Sensitivity 3.7V/lux-sec@550nm Mini illumination 0. 1lux Shutter Type Electronic rolling shutter / Frame exposure Connecting Port type USB2.0 High Speed Free Drive Protocol USB Video Class（UVC）	$81.99

			Support OTG Protocol USB2.0 OTG AEC Support, AEB Support Adjustable parameters Brightness, Contrast, Saturation, Hue, Sharpness, Gamma,Gain, White balance, Backlight Contrast, Exposure Lens Parameter: M9 Lens HOV 90 degree,optional M12 no ditortion lens, wide angle 180degree lens USB Interface Micro USB Operating Voltage DC5V/Operating Cuttent 160mA~220mA Working temperature -10～70℃/ Storage temperature -20～85℃ Board size /Weight 80X16.5mm, about 30g Cable Standard 1M	
LIDAR	Sparkfun	LIDAR Lite V3	Range: 0-40m Laser Emitter Accuracy: +/- 2.5cm at distances greater than 1m Power: 4.75--5V DC; 6V Max Current Consumption: 105mA idle; 130mA continuous Rep Rate: 1--500Hz Laser Wave Length/Peak Power: 905nm/1.3 watts Beam Divergence: 8m Radian Optical Aperture: 12.5mm Interface: I2C or PWM 20 x 48 x 40 mm (0.8 x 1.9 x 1.6 inches)	$130
		Team		
Team Members	Undergrads	Electrical, Mechanical, Computer, Software, and Industrial Engineering	25	N/A

Appendix B: Outreach Activities

Since the team was founded, in 2017, it has participated in various outreach activities. As a team that encourages gender equality, we prioritize educational activities for all levels; where we focus on the importance of inclusion.

On May 2018, the team participated in the Mechanical Engineering One Day Camp for girls ages ten to seventeen. The team members became their group proctors and were tasked with teaching the young girls about how they can get involved in STEM related activities without being marginalized by society. Also, in September, our team hosted a Mock Interview/Resume Workshop for students of all faculties in the university to which Baxter, ABB and V2A provided the resources for our event. With the University Open House, on October 19th, 2018, the team's attention was directed towards high school students from tenth to twelfth grade. The team chatted about what college is like and how enriching the experience gained from working in special projects like the RoboBoat is. Hosted by the ASEE, the team also participated in the Engineering Fun Day, a one-day camp for high schoolers during the month of March 2019. Members spoke to students about how our project came about and how they can be part of it once in college.

Figure 8: Mock Interview Workshop.

Figure 9: ASEE Engineering Fun day Info table.

Our last outreach event took place on May 2019, we participated in the Mechanical Engineering Girl Day and Boy Day. Both events focused on making the children feel like studying in a STEM field is not impossible. The team set up a pool and gave children the opportunity to control the boat remotely.

Figure 10: ME Girl Day Presentation.

Future projections include hosting a major outreach event for twelfth grade students in the east side of Puerto Rico. This is because that area receives less outreach from major STEM universities and college. This will ensure that students feel empowered and inspired but most importantly, educated in topics like gender equality, special projects, different engineering and business branches, opportunities in the university and professional development.