Lehigh University RoboSub Technical Design Report

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Abstract

The Lehigh University Underwater Robotics Team began work in summer of 2021. In our first year of competition, we strive to lay the groundwork for competitions in the future years and research acoustic signal processing, underwater visual simultaneous localization and mapping (SLAM), and a comparative study on multi-channel PWM drivers. Four sub-teams–*mechanical, electrical, software,* and *business*–work together to design and manufacture the autonomous underwater vehicle (AUV), named Osprey, at Lehigh Underwater Robotics. Each team takes on a number of tasks and communicates and collaborates together to produce the final product. The electrical team provides the computer and hardware as well as the power supply that the mechanical team uses for the drone's thrusters and other components. The software team programs the robot to perform the competition tasks autonomously. The business team focuses on documentation and organization of funds.

1 Competition Strategy

1.1 Team Makeup and workflow

The team is made up of four subteams: *mechanical, electrical, software* and *business*. Each team is responsible for designing certain components of the drone and collaborating so that each element fits together accurately.

As a team, overarching goals are set, outlined by the RoboSub requirements. There is a general team leader and four sub-team leaders who are responsible for administration and defining and enforcing sub-goals. These sub-goals are defined in order to achieve the larger goal by breaking it up into smaller tasks; they get accomplished on a daily or weekly basis, and build upon themselves to accomplish the larger goals.

1.2 Software Strategy

The main task of the software sub-team is to build on the work of the mechanical and electrical sub-teams and integrate all the results to run smoothly. In this process, we use several different methods to collaborate and achieve the results we require. These methods include training models for image recognition using YOLO [1], real-time image processing, use of models in OpenCV, programming in Python (and then using C++ to improve efficiency later), and control of AUVs using ROS and MavROS.

1.3 Mechanical Strategy

Team communication Due to part of our team being virtual we had to find a way to effectively communicate with the whole team. We solved this issue by having those who could be in-person meet up everyday to work, and those that were virtual work remotely while having the whole team communicate ideas over Slack (a collaborative team app), thus allowing all members of the team to remain included and work together effectively. *Settling on Designs* Often when our team was designing a component for the chassis we'd come up with multiple viable designs. The team would come together to discuss the pros and cons of each design and reach a consensus on which solution works the best.

1.4 Electrical Strategy

The electrical sub-team has the essential job of supplying our drone with power and ensuring that all of the components will be powered and operate when instructed to. The software and mechanical team are both reliant on the electronics to power the thrusters as well as the sensors that provide crucial localization information. This is the first time the Lehigh Underwater Robotics team will be competing in the RoboSub competition, so our first challenge is to design a power distribution schematic to supply an adequate amount of power to all of the AUV's components. Our electrical team used the BlueROV2, created by BlueRobotics [2], as inspiration to help guide the basis of our design. There were modifications that our team had to make in order to incorporate additional components not found in the BlueROV2 (Pixhawk 4, NVIDIA jetson, additional cameras, a gripper, etc).

1.5 Business Strategy

The business team works closely with the three other teams to understand what their tasks and contributions are. They contribute to compiling the documentation in the TDR, the team video, and weekly team update. Additionally, our team works with outreach in getting interest from new members and potential sponsers.

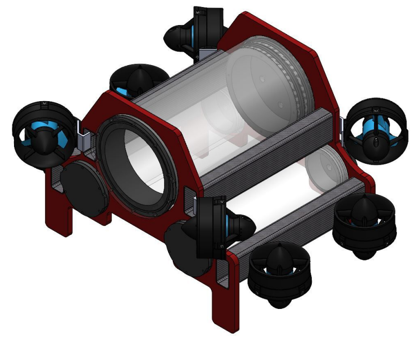

Figure 1: Mechanical design for underwater drone.

2 Vehicle Design

2.1 Mechanical

2.1.1 Frame

Marine grade plastic and carbon fiber nanotube are used for plates and connectors, respectively. These materials are lightweight alternatives to aluminum or other metals without compromising structural integrity.

One of the main considerations taken into account while designing the frame was the distribution of weight and buoyant forces. Specifically, the battery enclosures are positioned at the bottom of the frame and the main enclosure is positioned towards the top of the frame, between the two battery enclosures. This detail, as seen in Figure 1 allows the design to have a stable equilibrium when in the upright position due to the net downward force of the batteries and the net upward force of the main enclosure while underwater. These forces were calculated using the volume of air in the enclosure compared to the weight of the components inside.

2.1.2 Thrusters

Positioning: We wanted to maximize forward and backward movement speed while also having the robot remain maneuverable with many degrees of freedom. We used the same thruster layout from the BlueROV2 because we had already developed software in Summer 2021 compatible for controlling the thrusters. The team did not yet consider the ben-

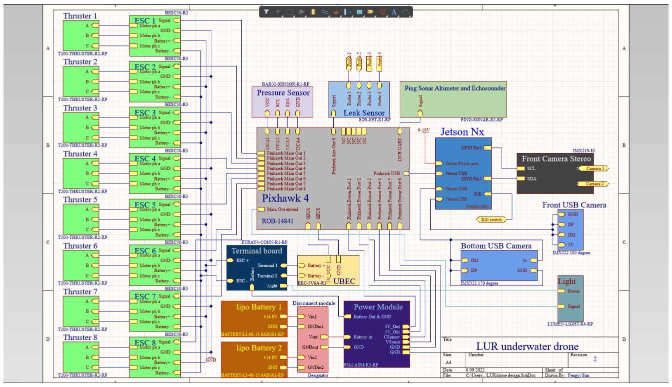

Figure 2: Electrical Schematic for underwater drone.

efits and disadvantages of another layout and did not have access to a simulation showing the advantages and disadvantages of other thruster layouts.

Mounting: A major concern of ours was how to mount the thrusters to match the correct positining while also making sure it would retain its structural integrity, remain intact, and remain balanced in the event that the robot hit an object while moving underwater. This was especially important for the top, angled thruster mounts. The angling on the thrusters cause the mounts to lose structural integrity, and the thrusters and mounts stick out from the main body of the chassis which makes them more fragile.

2.1.3 Torpedo Launcher

The goal in designing a torpedo launcher was to keep it as simple as possible. Our design relies on one servo with a gear that moves a linear actuator allowing for a torpedo to be released from the housing. The torpedo is propelled by a spring that is held under tension by the torpedo and the linear actuator. A notch all the way around the radius of the torpedo allows the torpedo to fit into the flat length of the linear actuator and hold the spring down, creating positive potential energy in the system. When the servo translationally moves the linear actuator to one side, the torpedo is released from tension and the spring propels it forward into the required space for scoring points.

2.2 Electrical

2.2.1 Design Obstacles

One of the major design obstacles the electrical team faced was installing the entire hardware system inside of a water-tight acrylic tube. The electrical team collaborated with the mechanical team to design and print a harness that would safely secure all of the AUV's hardware.

The electrical team also works closely with the software team to select the best sensors to implement into the AUV. This collaboration is critical since the selection and wiring of sensors is what will provide the software with sufficient data to successfully navigate through the tasks.

2.2.2 Battery

Our drone is powered by two lithium-ion batteries connected in parallel (supplying 14.8V). The electrical team decided to use a low voltage disconnect module, switching between batteries when the battery dropped to a certain level, to protect the batteries from discharging too much and causing permanent damage.

Then, a few UBECs (V-V converter) are implemented to supply the desired voltage (5V) to power the Pixhawk 4 [3]. The voltages are distributed via terminal boards and power the whole system. We are using the Pixhawk 4 as our AUV's flight controller. The flight controller controls all 8 thrusters, the leak sensor, and the pressure/depth sensor and communicates this data into the Nvidia jetson. The Jetson (central processing unit) would then analyze these data along with the data obtained from the three cameras connected directly to the Jetson. The schematic is seen in Figure 2.

2.3 Software

We will mainly use ROS2 [4], YOLO [1], and OpenCV [5]. Robot Operating System 2 (ROS2) is an open-source software development kit for robotics applications. Using it can help us save time on integrating different robot functions. You Only Look Once (YOLO) is a real-time object detection algorithm. Using YOLO is easy to train with the custom data set, which can be an excellent way to recognize the image in the different tasks. OpenCV is an open-source computer version platform library and using it can provide a good way to use the drone in a little to no data training situation.

2.3.1 Image recognition

OpenCV [5] is an open-source code, and using it can help reduce a lot of processing power compared to the other machine learning platforms, and we can do the edge detection for the gate and help us find and locate the position of the gate buoys with ease. The grayscale and color isolation make it easy to locate the gate. We use YOLO to train a custom model for the image on the gate and the buoys in the task. YOLO is a solid open-source neural network code that can use limited data to get a good image recognition result. Therefore we do not need to collect tons of data. We can still get a good result by just using a small number of pictures collected from the drone.

2.3.2 Motion Control

MAVLink [6] is a lightweight messaging protocol for communicating with drones. This provides an easy way to communicate with the different parts of the drone and send control signals, with thrusters, the battery, and different sensors. MavROS is a ROS package that enables MAVLink communication between computers using ROS.

3 Experimental Results

3.1 Pool Tests of BlueROV2

Testing has been done over the past six months in one of the pools on our University's campus. We used the BlueRobotics BlueROV2 for most of our testing, where we recorded video and tested Python scripts on its Raspberry Pi. As we moved to our own design, we test scripts in ROS or Python on the Nvidia Jetson. The video footage was collected for training our models for autonomy.

In addition to the BlueROV2 which has a Raspberry Pi, we designed an enclosure containing the Nvidia Jetson and a camera for testing that is more like the new design, as the camera is the same. This device does not include thrusters, so instead a member swimming in the pool guides it manually. We used a script to record the video, where it waits a certain amount of time to start recording as we get the device ready for the water, then records for a set amount of time. Then, we download the file using SSH file transfer protocol (SFTP) or secure copy (SCP). This video is used for training the model, and the design of the enclosure provides the same footage that Osprey would see.

3.2 Bouyancy Testing of Carbon Fiber Frame

The new design has a different structure than the BlueROV2 we used for testing; therefore, it has different balance and buoyancy. We needed to calculate the buoyancy so it is positively buoyant as required, but we did not have an estimate on how it would behave in the pool. So the team placed it in a tub to feel how it is balanced and where buoyancy foam or weights may need to be placed.

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We would also like to thank our donors from crowdfunding, who helped make our drone possible. Finally we thank Lehigh's Mountaintop Program for providing the groundwork and funding on our team project.

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Appendix A

Component	**Vendor**	**Model/Type**	**Specs**	**Custom/ Purchased**	**Cost**	**YOP**
Battery Check (2)	BlueRobotics	BATTERY-CELL-CHECKER-R1	2-6s Li-Ion Battery	Purchased	$30	2020
Cable Plugs (16)	BlueRobotics	PENETRATOR-BLANK-VP	M10 Threads	Purchased	$64	2020
Battery Cables (2)	BlueRobotics	BROV2-CAB-POWER-SET-R1-RP	5.5mm	Purchased	$136	2021
I2C Converter (1)	BlueRobotics	LEVEL CONVERTER-R1-RP	3.3V	Purchased	$20	2020
Watertight Enclosure (1)	BlueRobotics	WTE6-ASM-R1-VP	6” Series	Purchased	$337	2021
Dual Row Terminal Strip(1)	GUBCUB	GUB-JXDZ	10.0 A	Purchased	$6.99	2021
Voltage Disconnect Module (1)	CZH-LABS	MD-D1021V3 Series	12V/30A	Purchased	$25	2022
Rechargeable Li-Ion Battery (2)						
Orange Plastic Sheet (2)	BuyPlastic	PLA-000018-020	11.75” x 23.75”	Purchased	$21.46	2022
Dropper Brushless Servo(1)	Traxxas	e-revo Slash T-maxx Summit 3908	6 V	Purchased	$39.95	2021
Camera	ELP Sony	IMX322/323	100° FOV	Purchased	$63.99	2022
Camera	ELP Sony	IMX322/323	170° FOV	Purchased	$62.99	2022
Plastic Sheet (2)	ePlastics	SEABOARDBLK-0.500TEX54X48	1” X 54” X 48”	Purchased	$268.26	2022
Watertight Enclosure (2)	BlueRobotics	WTE3-P-TUBE-8P75-R1-RP	3” Series	Purchased	$262	2022
SOS Leak Sensor	BlueRobotics	SOS-SET-R1-RP	3.3-5V, 20mA	Purchased	$32	2021

Component	Vendor	Model/Type	Specs	Custom/ Purchased	Cost	YOP
Pressure/Depth Sensor	BlueRobotics	BAR30-SENSOR-R2-RP	30 Bar (300m)	Purchased	$85.00	2021
Ping Sonar	BlueRobotics	PING-SONAR-R3-RP	30° Beam width, 300m	Purchased	$360	2021
Pixhawk 4	HolyBro			Purchased	$190	2020
Thrusters (8)	BlueRobotics	T200-THRUSTER-BROV2-CCW-SPARE-R2-RP		Purchased	$1,680	2020
Nvidia jetson Developer Kit	NVIDIA	Nano	4GB	Purchased	$99	2020
ESC(8)	BlueRobotics	BESC30-R3	7-26V	Purchased	$288	2022
Circuit Breaker	Bumbesti	HBD-CXFH-15A-2P	15A	Purchased	$19.99	2022
Diodes (2)	Onsemi	MBR40250TGOS-ND				