MARVL-ROV: Modular Adaptable Research Vehicle Loadout for the BlueROV2

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I. Introduction

Marine robotics research has been revolutionized with the advent of low-cost remote operated vehicles (ROVs) such as the BlueROV series from Blue Robotics. Increasingly, it incorporates advances from the field of deep learning which are instrumental in transforming and modernizing undersea exploration, monitoring (tracking changes in size, coloration of marine species, et cetera), 3D mapping, mission control, marine biology (such as identification of marine species), and data efficiency (sifting through large volumes of data).

In view of this, however, there is still a lack of open-source designs available to help researchers upgrade the standard BlueROV2 to fit the needs of contemporary marine robotics research. From the few open-source designs which are available, we aim to fill the gap in the design of low-cost ROVs. LoCo [1] is a well-known low cost design for a barebones autonomous underwater vehicle (AUV) using parts from the BlueROV2, while we aim to retain the original BlueROV2 design for standardization and fit additional compartments and sensors on top. HAUV [2] on the other hand features an onboard GPU-enabled computer upgrade to the BlueROV2 with two pairs of stereo camera setups, while we aim to enable the fitting of as many sensors in the ROV in a compact way, as sensors are crucial in pushing the frontier in marine robotics.

In this paper, we propose an open-source, low-cost, modular BlueROV2 upgrade schematic for onboard AI-enabled edge computing with an array of optional sensors.

II. Methodology

A. System Design

The original BlueROV2 is powered by a Raspberry Pi 4B computer (RPi) which is not suited for AI edge computing. Our design goal is not to replace it but augment it with a compute module for vision and other AI tasks, and thereby decouple flight control (RPi) from AI compute. They are to be connected via a local physical network enabling exchange of data and commands between the two modules, with additional sensors made available to both via the local network.

Figure 1 shows the perspective view of the overall design of the MARVL-ROV upgrade with a breakdown of the components of the AI module, additional sensors, and several mechanical modifications.

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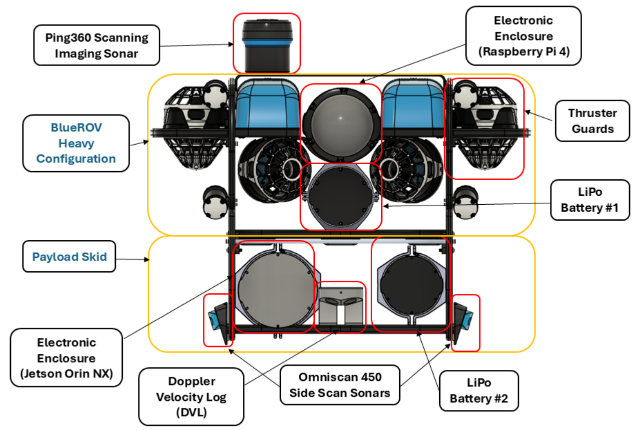

Fig. 1. Components Breakdown of Upgraded BlueROV2

B. Mechanical

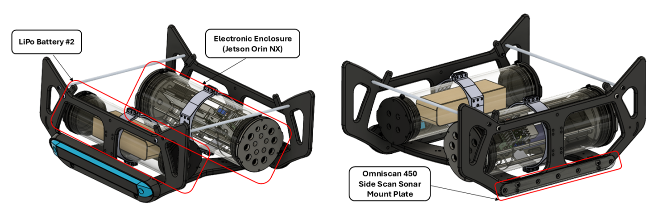

Fig. 2. Left: Payload Skid, Right: Side Scan Sonar Mount Plate

1) Payload Skid: The payload skid serves as an additional structural frame to the BlueROV2 (which may use Heavy Configuration) for mounting an additional battery, electronics enclosure containing Jetson Orin NX for the AI capability, and optional sensors such as side scan sonar as shown in Figure 2. As the original design of the payload skid was not intended to mount the side scan sonar, an alternative solution has been developed based on the design constraints of the mounting holes through the fabrication of an acrylic mount plate for the sonar as shown in Figure 2.

2) Thruster Guards: The original design of the thrusters faces the issue of being entangled with kelp while maneuvering in the sea, disrupting mobility and sensor clarity. Hence, we custom-designed thruster guards with respect to the mounting constraints of T200 thrusters for 3D printing and installed them onto the thrusters. Further trials of the thrusters with the thruster guards have been implemented, showing that the design has succeeded in minimizing kelp entanglement and maintain the propulsion effectiveness of the thrusters.

C. Electrical

1) Control Module with Raspberry Pi 4B: The control stack is identical to the original BlueROV2 enclosure, with the addition of an Ethernet Switch which allows connection to the lower AI module. The Ethernet Switch further links this top control stack to the lower vision stack enclosure via Ethernet, using fathom tether, and fits two additional devices such as the DVL A50.

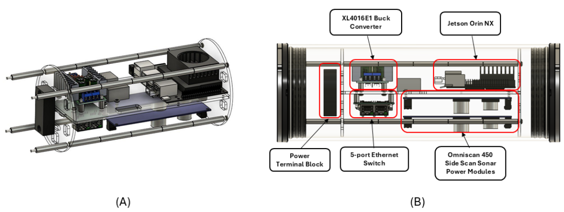

Fig. 3. Left(A): Mounting Frame for Electronics, Right(B): Electronics Enclosure (Vision/AI Module)

2) Vision/AI Module with NVIDIA Jetson Orin NX: Inspired by the BlueROV2 electronics enclosure, Figure 3(A) shows a similar mounting frame design with stronger stainless-steel stands to hold the two round plates together that act as an electronics tray for rapid visual inspection of the electronics. Furthermore, this design ensures the structural integrity of the mounting frame as the electronic tray would often be removed from the enclosure for troubleshooting.

Figure 3(B) shows the electronics enclosure used to power the Jetson Orin NX and communicate with the Raspberry Pi 4. The power terminal block, connected to the LiPo battery, connects to the buck converter. The buck converter steps down the input voltage to operating voltage of Jetson Orin NX, the 5-port Ethernet Switch and the Side Scan Sonar Power Modules. The lower Ethernet Switch connects the Orin NX to the Raspberry Pi 4 via the top Ethernet Switch for vision-control communication. It also connects the additional sensors such as side scan sonar.

D. Communications

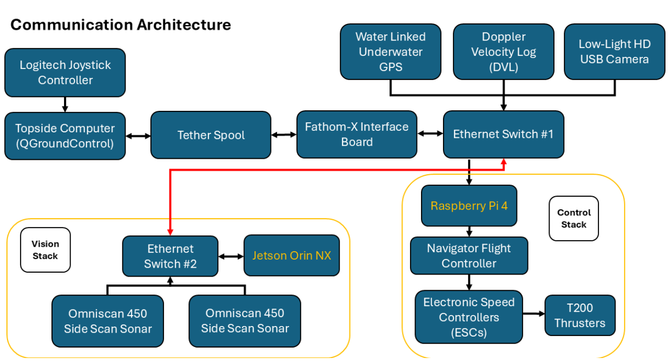

Fig. 4. Communication Architecture

Figure 4 shows the communications architecture which we propose. The 2 Ethernet Switches act as communications relay between the Raspberry Pi 4B and Jetson Orin NX and additional sensors. This system is suitable for autonomous tetherless configuration with vision and control module communicating with one another, or for tethered operation for supervised autonomy or semi-autonomy.

III. Experiments

The cost of the design without Heavy Configuration and without the additional sensors is 7000 USD.

From the testing that we have done, our design is able to maneuver well in freshwater and saltwater smoothly and stably. The buoyancy is stable. Sensors are running well with sufficient power distribution, while communication between topside and ROV, and between control and vision is smooth. This upgrade has shown robustness and achieved the design goals and maintains modularity. Figure 5 shows the upgraded BlueROV2 in action in freshwater.

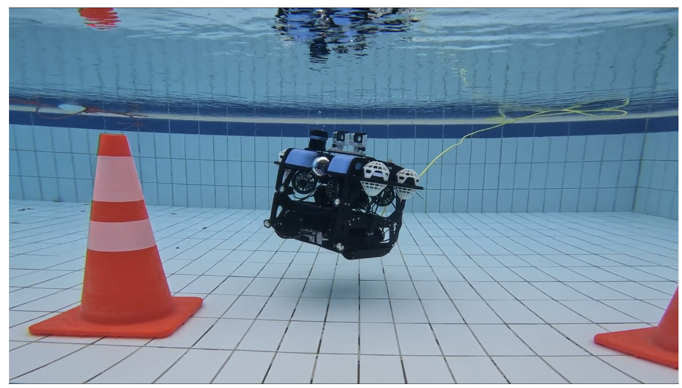

Fig. 5. MARVL-ROV in action

IV. Acknowledgement

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