RoboSub 2024 Technical Design Report

Widener University

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***Abstract*— This is the first time that Team Pride from Widener University participates in the RoboSub competition (RoboSub 2024). An autonomous underwater vehicle (AUV) was designed and built by the team with a vectorized thruster configuration, and a underwater gripper. Multiple onboard sensors are integrated to the AUV to support navigation, underwater objects detection and recognition, and acoustic signal acquisition. Two onboard microprocessors are used to process sensor data, fuse information from different sensors, and make AUV operation decisions. Software was developed to implement all data processing and decision-making tasks using Robot Operating System (ROS) and Python. Each AUV component was tested individually, and the AUV was tested at Widener University swimming pool to evaluate the system performance and functionality. The opportunity exists for the further improvement of the current design and implementation before the competition.**

Figure 1: CAD Render of The Pride

I. Competition Strategy

For the first time at Widener University, after 3 years of development, a team of engineers will be competing in the RoboNation RoboSub 2024 competition.

A. Strategy

Competing with our singular AUV labeled "The Pride" (Fig. 1), after breaking down the Team Handbook provided by RoboSub, The Pride is built to handle the basic navigation and tasks involving the Subsea gripper.

For vehicle navigation and position a ICM-20649 Adafruit Inertial Measurement Unit (IMU) has been installed and wired into a Raspberry Pi 4B. Through our developed software the IMU values are used in coordination with our six BlueRobotics T200 Thrusters to keep the AUV stable while an Arducam 1080P USB Camera keeps the AUV on track for the beginning stages.

After the beginning stages involving color tracking, a H2C Hydrophone is used to detect sonar pings under the water, where the Raspberry Pi will decipher and coordinate with the thrusters to direct the AUV towards the remaining tasks. As this is the first year The Pride will be competing there are certain tasks that it will be unable to perform, such as the Torpedo launching. In the future it is planned that these abilities will be added.

II. Design Strategy

A. Engineering Standards

Specific engineering standards are considered during the design phase to ensure safety so that the team can properly build, power, and operate the

AUV, including the standards set by the American Bureau of Shipping (ABS) and National Electric Code (NEC) stated in the Appendix. For example, ABS standards provide guidance for AUV body materials, and layout of the electrical systems and power sources. Following the NEC standards to ensure sufficient wire insulation and secured connections, minimizing the risk of firing break out and electric short.

B. System Level Design

The system level design is divided into three parts: AUV body, electronics, and software.

(1) AUV Body

Considering the RoboSub 2024 Vehicle Requirements, the AUV must fit within the dimensions of 3ft × 3ft × 6ft and remain less than 125 lbs. The frame of the AUV was designed to allow a vectorized motor configuration without exceeding the dimension restriction (Fig 2.). Four thrusters are mounted on the corners at 45° from forward, and two additional thrusters on the sides oriented vertically for up and down motion. The AUV's weight has been limited to approximately 30 pounds.

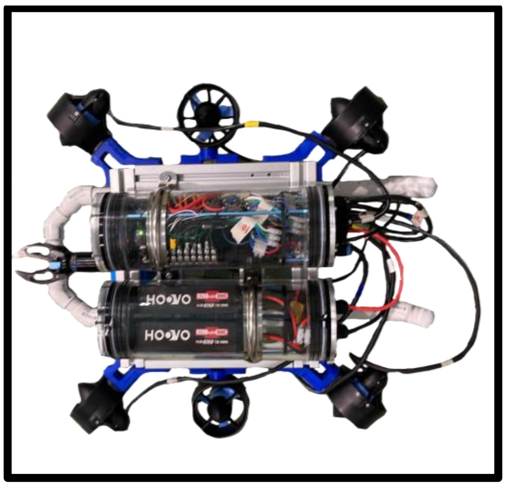

Figure 2: The AUV Body

The frame is constructed using two types of material. One part is made of aluminum extrusion, and the motors, acrylic tubes, and gripper are mounted to this part. Two acrylic tubes are used with watertight connectors. One tube contains the electronics and the second the batteries. The other portion of the frame is constructed from PVC pipe. It fits around the body of the AUV and is filled with foam to increase the buoyancy of the AUV.

An underwater gripper is attached to the frame of the AUV near the camera so that the AUV can position itself near an object using the camera and then grab the object and move it to a prespecified location.

(2) Hardware

Considering the size constraints presented by attempting to fit the electronics of the AUV into a single enclosure so that the second enclosure can host the batteries thus reducing weight and overall cost.

The main controller for the AUV are two Raspberry Pi 4 Model Bs (Fig. 3). These single-board computers were chosen for their versatility and simple multiple processing capabilities. One Raspberry Pi was used for controlling and driving the motors and doing vision processing. The second Raspberry Pi was used for reading data from multiple sensors.

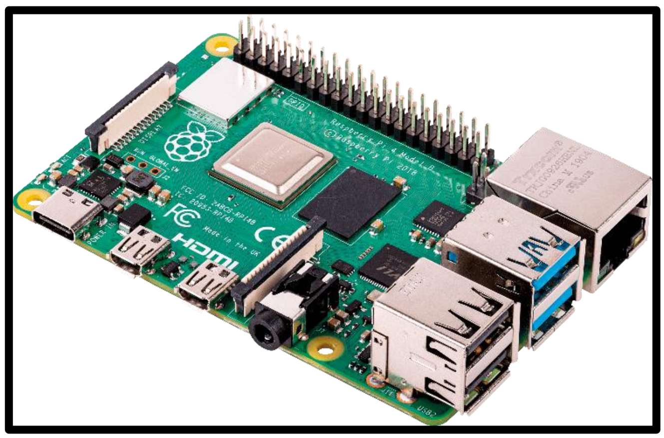

Figure 3: Raspberry Pi 4 Model B

Since there were more motors than there are PWM pins on the Raspberry Pi, a separate board was used to drive the motors and the gripper as they all use PWM signals to determine their speed and direction. The board chosen was Adafruit's PCA9685 servo driver (Fig. 4). This board would mount directly onto the Raspberry Pi automatically connecting via I^2C simplifying wiring.

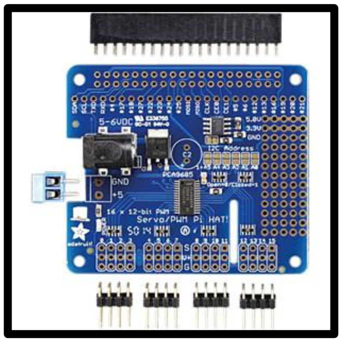

Figure 4: Adafruit's PCA9685 Servo Driver Board

The thrusters chosen for the AUV are the BlueRobotics T200 thrusters (Fig. 5). These underwater thrusters were chosen as they are quite popular thrusters and provide more than enough thrust to manipulate the AUV.

Figure 5: BlueRobotics T200 Thruster

To drive these thrusters the BlueRobotics Basic ESC (Fig. 6) was chosen as it is the typical ESC used for these thrusters. The ESC utilizes PWM signals to control both speed and direction. One was used for each thruster present on the AUV.

Figure 6: BlueRobotics Basic ESC

Additionally, for the gripper, the BlueRobotics Newton Subsea Gripper (Fig. 7) was chosen as it was a simple and reliable gripper sold by BlueRobotics. Additionally, this gripper utilizes a PWM signal to control it. Conveniently, the same PWM signal given to the thrusters can be given to operate the grippers thus simplifying programming.

Figure 7: BlueRobotics Newton Subsea Gripper

To determine the position and depth of the AUV two sensors were used, the ICM20649 inertial measurement unit (IMU) by Adafruit (Fig. 8) and the BlueRobotics Bar30 depth sensor (Fig. 9). Both sensors communicate via I2C thus simplifying wiring and programming. Additionally, the Bar30 depth sensor can easily mount to the outside of the AUV simplifying the design process.

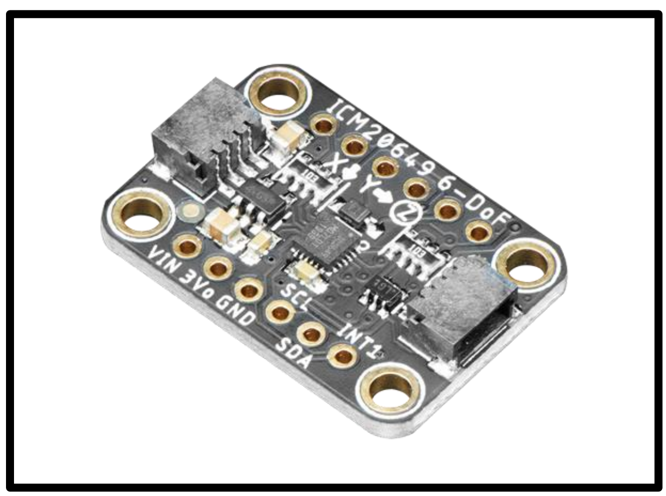

Figure 8: Adafruit ICM20649 IMU

Figure 9: BlueRobotics Bar30 Depth Sensor

The final sensor used is the Aquarian Hydrophone H2C (Fig. 10). This is a submersible microphone typically used to record ocean sounds; however, this will be used to detect pings for the competition.

Figure 10: Aquarian H2C Hydrophone

To make the input usable for the Raspberry Pi, the hydrophone is fed into an ADS1115 (Fig. 11) analog to digital converter (ADC) breakout board with a built-in amplifier. This ADC communicates via I^{2}C which simplifies programming and wiring.

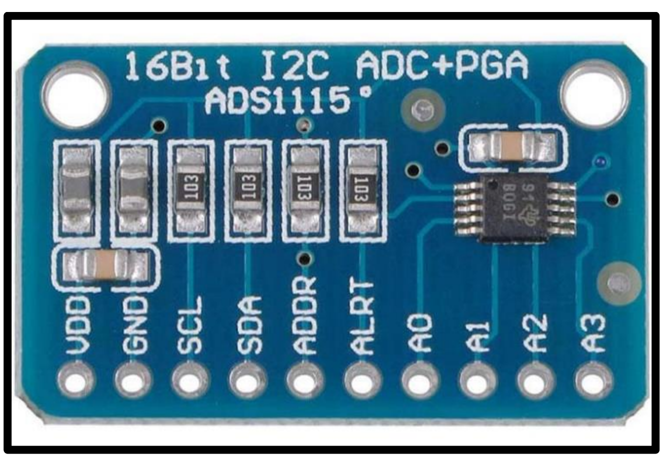

Figure 11: ADS1115 Analog to Digital Converter

To power the AUV, two HOOVO 14.8V 9200mAh 100c batteries (Fig. 12) were used for the thrusters and gripper. These were chosen for their high capacity at a relatively low cost. This allows us to draw a significant amount of current from the batteries and should give the AUV plenty of runtime for the competition.

Figure 12: HOOVO 14.8V 100C 9200mAh Batteries

Additionally, an INIU 10000mAh power bank (Fig. 13) was used to power the remaining electronics. The benefit of using this is that the electronics can run while the thrusters and grippers are powered off in an emergency. Additionally, this makes the testing of the thrusters and the electronics separately much simpler for troubleshooting.

Figure 13: INIU 10000mAh Power Bank

(3) Software

The software was designed to be modular to simplify debugging and programming. The software for all the I^{2}C sensors was added to a single file so that they can be accessed easily. Additionally, the motor and gripper control code, and the camera's image recognition code were written in separate files.

Because of everything being in separate files, a single file held all the control code where it would draw from each individual file and take information accordingly. This was chosen to allow for each part of the code to be changed simultaneously and without severely affecting the functionality of the rest of the program.

III. Testing Strategy

A. Waterproofing

To test the watertightness of the AUV's enclosures, they were first assembled without anything in them ensuring the O-rings were lubed before installation and sealing. The enclosures were first tested by placing them under running water and checking to see if any water entered the enclosure after drying the outside.

Following this, after the AUV was assembled and the electronics placed inside the enclosure, the entire AUV was placed inside a swimming pool 5ft deep for 15 minutes to an hour. Following this, the inside of the AUV was inspected to ensure no water entered the enclosure. This test was repeated at 13ft as well.

B. Electronics

The electronics for the AUV were first tested as standalone parts. The first things were the thrusters, ensuring that after wiring the thrusters to the ESCs and the ESCs to the PCA9685, a noise would be heard signifying the thrusters were live. Following this, a bit of code was written to write to a single thruster at a time having it ramp up in speed, slow down then shut off. This process was repeated for each thruster.

Following this, using a similar setup, the gripper was tested to ensure that it would operate properly. Most notably, that the gripper would sense when it has gripped something to avoid damaging the motor.

Every sensor was tested by having a bit of code written to read from it. It was tested against some real values to ensure that they provide satisfactory results and that they changed accordingly. For instance, with the IMU, the IMU was moved to ensure that the accelerometer and gyroscope values changed as the IMU moved.

The camera vision was tested by putting different colors and pictures in front of the camera and tuning it until it provided satisfactory results. Following this, we used text to indicate what the AUV would do based off what was recognized. This includes moving forward, moving left, right, etc.

C. Thruster Control

The thruster control scheme was tested by writing basic code for moving the AUV in three directions and for roll and yaw. As the AUV moved underwater, values were adjusted until the AUV moved as desired, and that every thruster functioned as desired.

IV. Conculsion

Team Pride from Widener University has successfully designed and built an autonomous underwater vehicle (AUV) named "The Pride" to compete in the RoboNation RoboSub 2024 competition. This marks the team's inaugural entry into the competition, following three years of dedicated development. The AUV features a vectorized thruster configuration and an underwater gripper, enabling it to perform basic navigation and task-oriented functions.

Our design strategy emphasizes safety and adherence to engineering standards, utilizing robust materials such as aluminum extrusion and PVC pipes, complemented by a buoyancy-enhancing foam structure. The AUV's hardware integrates multiple sensors, including an IMU, depth sensor, hydrophone, and camera, all managed by dual Raspberry Pi 4B microprocessors. The software, developed using Robot Operating System (ROS) and Python, is modular, facilitating efficient debugging and functionality updates.

Extensive testing at Widener University's swimming pool has validated the watertightness, electronics performance, and thruster control of the AUV. While "The Pride" is prepared for its debut competition, opportunities for further enhancements, such as the addition of torpedo launching capabilities, have been identified for future iterations.

The journey to RoboSub 2024 has been a significant learning experience for Team Pride, showcasing our ability to innovate and collaborate effectively. We look forward to demonstrating our AUV's capabilities in the competition and are committed to continual improvement and excellence in underwater robotics.

Acknowledgments

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