Texas A&M University Women in Engineering Autonomous Underwater Vehicle Team

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Abstract**—The objective of the Women in Engineering's Autonomous Underwater Vehicle (WE AUV) Team was to design an efficient and reliable vehicle capable of performing the coin flip, gate, buoys, and bins. This was to focus on maximizing the total points that could be earned with the limited resources the team had to program and design the AUV.**

Throughout the season, mechanical, electrical, and programming substeams worked concurrently to develop the AUV. Mechanical subsystems include the hull, external frame, and internal frame. Electrical systems were developed on three custom PCBs for GPIO, ESCs, and hydrophone processing. Programming advancements were made in computer vision and ROS.

Keywords—Autonomous Underwater Vehicle, Women in Engineering Program, PCB, machine learning, PID, ROS

I. COMPETITION STRATEGY

A. General Strategy

Our primary goal of the competition is to have the robot pass through the gate and surface. As this is the most important obstacle to overcome in order to move forward in competing.

B. Gate Task

Most of our focus was placed on getting our vehicle optimized and capable of passing through the gate. This was done by calibrating our 8 thrusters to ensure they change the robot's path in precise and predictable amounts. The sensors on the AUV were integrated such that the information they gathered would inform the amount that the AUV's path needed to be altered to pass through the gate.

C. Coin Flip Task

For this task, a Deep Learning camera model uses detection to ensure the robot's correct orientation to the gate before activating the thrusters to move accordingly. ROS evenly distributes power to the thrusters based on sensor and camera data in order to stay in the ideal position.

D. Buoy Task

The buoy task can be found by following the path in the water after the gate task. Our Deep Learning model will detect this marker and follow the direction indicated until the buoy can be seen. It will then detect the appropriate symbol on the bout so our vehicle can bump into it.

E. Bin Task

This year, the team decided to skip the bin task. We wanted to place most of our focus on the gate and qualifying by implementing several new programming aspects to our vehicle that took time to learn about.

F. Torpedo Task

Similarly to the bin task, we skipped the torpedo task to focus our attention elsewhere.

G. Octagon Task

The octagon task can be completed by using our Deep Learning model to detect the symbols. As the focus of this year's vehicle was on the Deep Learning models and autonomous movement, designing a mechatronic attachment was not necessary to complete this task.

II. DESIGN CREATIVITY

A. Mechanical Creative Aspects

1) *End Caps:* The end caps were fabricated from aluminum with a polycarbonate cut out for the camera's placement. For aesthetic purposes, our school mascot and logo were laser engraved onto the face.

2) *Hull*: The hull was made from leftover polycarbonate tube from the team's previous AUV. This was chosen over the initial hull design to reduce manufacturing costs and time. The initial hull design was octagonal and planned to be manufactured out of aluminum welded together but manufacturing costs were extremely high. The clear polycarbonate also allows for the camera vision ability and for the team to see if the electrical components in the internal frame are working properly.

3) *Internal Frame:* The internal frame was designed with plates consisting of holes, so the electrical components could easily be installed with screws and zip ties. This allowed for simplistic installment and sensors and electronics to be easy to reach.

4) *Legs*: The legs were manufactured out of a ⅛" aluminum sheet utilized to attach the thrusters and support the external frame. The cut out patterns were created to reduce drag on the AUV when in water.

B. Electrical Creative Aspects

1) *ESC PCB*: The ESC, electronic speed controller, controls the speed of the thrusters, and all eight thrusters contain an ESC. An ESC consists of three-pin inputs, which are power, ground, and signal; as well as three-pin outputs, which are the three phases. Previously, the ESC controllers were held under one of the silicon wings of the AUV causing tangled overlapping wires. However, with the addition of the PCB, there's easier access for troubleshooting and cleaner wire management.

2) *GPIO PCB*: The GPIO PCB, which houses the Jetson TX2 GPIO pins and several six-pin

headers, was designed to offer more pins than the limited number available on the Jetson. The extended nodes on the PCB created by the headers are used to facilitate connections between the Jetson and other components, such as the Teensy and PWM, in order for them to communicate.

C. Programming Creative Aspects

1) *Camera*: Our Deep Learning model uses the Zed Mini Camera to detect objects underwater. The model was trained with a large dataset of images on MATLAB and converted to be used with Python and ROS. This allows us to prioritize and navigate to the appropriate tasks.

2) *ROS*: Robot Operating System is an open-source software that allows data transfer between the sensors and the robot. ROS is used to simulate an environment for the AUV and connect the sensors, computer, and microcontrollers. One of the main methods to integrate ROS with the AUV involves creating nodes that communicate data by publishing the topics for different components as well as commanding the thrusters to move.

III. EXPERIMENTAL RESULTS

A. Electrical

The Hydrophone Signal Processing (HSP) PCB seen in Fig. 1 allows us to read in signal data to autonomously move the AUV accordingly. The signal from the hydrophones goes through amplification, filtration, and analog to digital conversion (ADC). For the foundation of the signal processing circuitry design, we referenced an analysis textbook. [1] In order to calculate the bandpass filter's correct values for our specific frequency case, an online source was sought out. [2]

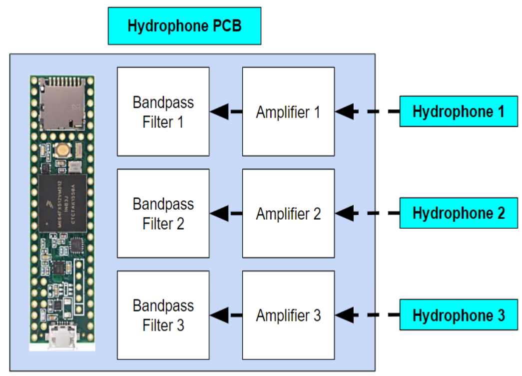

Fig. 1: HSP PCB Schematic Diagram

B. Programming

Our camera model was initially trained using Machine Learning on Roboflow and Google Colab. This did not produce a viable model, so we moved to using AutoML directly on Roboflow's website. Although this might have given us a model, there is no easy way to export the model to the Jetson. After researching alternatives, we decided to try MATLAB's Deep Learning. Many models were trained to improve accuracy by adjusting the image dataset until we were happy with its ability to detect our objects.

IV. ACKNOWLEDGMENTS

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V. REFERENCES

[1] F. T. Ulaby, M. M. Maharbiz, and C. Furse, *Circuit analysis and design*. Ann Arbor, Michigan: Michigan Publishing, 2018.

[2] "Dale's Homemade Robots - Bandpass Filter Calculator," *wa4dsy.net*. https://wa4dsy.net/robot2/bandpass-filter-calc (accessed Oct. 17, 2022).

Appendix A: Component List

Component	Vendor	Model/Type	Specs	Custom/Purchased	Cost	Year of Purchase
Frame	Metal Supermarkets	Aluminum 6061 T6	Additional bottom frame panel added to 2018-2019 AUV Frame	Custom	$50	2018
Hull: Tube	McMaster-Carr	Polycarbonate Tube	ID: 7 ¾", OD: 8", L: 8'	Purchased	$185.05	2018
Endcap	Online Metals	Aluminum 6061 T6	D:8 in H:1 in Thickness: ¼ in	Custom	$405	2022
Endcap Window	Home Depot	Clear Plexiglass Acrylic Sheeting	L: 8 in W: 2.5 in Thickness: ¾ in	Custom	$24.29	2022
Waterproof connectors	Subconn & Blue Robotics	Blue Robotics Cable Penetrators	Subconn: Circular series 12 pin	Purchased	$600	2022
Propulsion	Blue Robotics	T200	T200	Purchased	$1,352	2019
Motor Controls	Blue Robotics	R3	7-26 volts, 30 amps, Spade terminals, Tinned Wire Ends, L 1.38',W .67'	Purchased	$200	2020
CPU	NVIDIA	Jetson TX 2	8 GB, 59.7 GB/s of memory bandwidth	Purchased	Donated	2019
Inertial Measurement Unit	-	-	IMU is embedded in the stereo vision forward facing camera. See below.	-	-	-
Camera	ZED	ZED Mini	100 Hz FPS, 0.1 - 15 m depth range	Purchased	$399	2019
Algorithm: Autonomy	PID control	-	Thruster regulation	-	$0	-
Vision	OpenCV Deep Learning	4.6	Color Thresholding, Object Detection	-	$0	-
Programming Lang 1	Python	Python 3	Implemented on Jetson	-	$0	-
Programming Lang 2	Arduino	C programming - Register level	Implemented on Arduino Mega 2560	-	$10	-
Application Programming Interface	Keras	Keras 2.3.0	API built on top of TensorFlow 2.0	-	$0	-
Open Source Software 1	Github	-	Code organization	-	$0	-
Open Source Software 2	TensorFlow	TensorFlow 2.0	Python Library	-	$0	-
Open Source Software 3	ROS	Melodic	Data transfer	-	$0	-
Team Size	-	-	64 Members	-	-	-
HW/SW ratio	-	-	3:1	-	-	-
Testing Time	-	-	10 hours	-	-	-

Appendix B: Project Team’s Workshops

<u>*Project Team’s Workshops*</u>
Supported by the Women in Engineering Program at Texas A&M University

This year the team hosted a variety of in-person and hybrid workshops centered on developing technical skills and promoting professional development. These workshops were led by senior members of the team and aimed to provide introductory skills as a way to build confidence in members and provide a base level of knowledge to utilize in the design of our vehicle. A central focus of the professional development workshops was creating a safe space for team members to ask questions and share their experiences. Senior members of the team hosted an internship experience panel, an undergraduate research panel, and an Entry to a Major Panel, all of which were used to create a platform for sharing advice, mentorship, and experiences. In addition to these workshops, the team conducted two design reviews with Texas A&M professors and industry sponsors. These events were critical for receiving feedback and mentorship on our designs.

The following workshops were hosted this year:
Mechanical
- Introduction to SolidWorks
- Mill Basics
- Lathe Basics
- Solidworks Simulations

Electrical
- Circuits and Components Basics
- Multisim Basics
- Active and Passive Filters

Programming
- Introduction to Python and C++
- Introduction to Git and GitHub

Professional Development
- Internship Experience Panel
- Entry to a Major Q&A Session
- Getting Involved in Undergraduate Research Panel
- LinkedIn Workshop
- Industry Networking Events with sponsors
- Design Review with sponsors

Presentation at design review with industry sponsors

Presentations at Introduction to Git and GitHub Workshop