Robotics Association at Embry-Riddle: Team Unsinkable

Hasan Akpunar, Brooke Wolfram, Aaron Autry, Austin Haeberlen, Chandra Teja Tiriveedhi, & Sergio Carli

Embry-Riddle Aeronautical University, Daytona Beach FL

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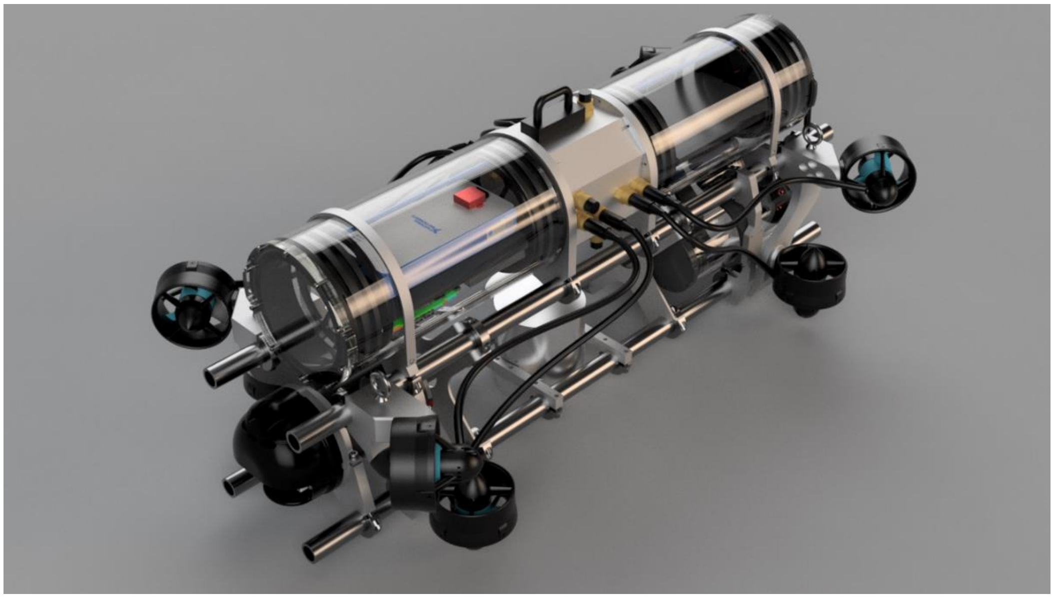

Abstract

Team Unsinkable from the Robotics Association at Embry-Riddle (RAER) is using a new custom-designed platform. The new platform, Nautilus, was designed for the 2020 Association for Unmanned Vehicle Systems International (AUVSI) Foundation RoboSub Competition. Nautilus was developed with universal compatibility and adaptability in mind. The platform is intended as the primary Autonomous Underwater Vehicle (AUV) for the team.

I. Competition Strategy

The strategy employed this season was to attempt simple and low difficulty tasks. It was expected that there would be many challenges and obstacles to overcome while designing a new Autonomous Underwater Vehicle (AUV). Having a larger emphasis on the development of the AUV such as configuring controls, vision, and various physical elements, and attempting low level tasks such as the gate and buoy would ensure success in future competitions. The goal was to achieve complete reliability in the gate and buoy tasks. Doing so would create a foundation that could easily be built upon in the future for more complex tasks.

The primary method used for autonomy was computer vision. Computer vision is something that the team has prior experience with and would yield the best results. While vision was a large focus, the team had discussed using more complex systems such as sonar and Doppler Velocity Loggers (DVL's) in the future. These systems were planned to be onboard the AUV even while not operative to transition smoothly to using them in future years. It was planned to have the systems collecting data that could be used to develop them into the platform when the time comes.

With a new and complex custom design, there was an issue raised regarding the reliability of the platform. Many precautions had to be taken and critical systems had to be planned meticulously in order to avoid failure. The team utilized faculty and graduate advisors to assist in all stages of development. Their advice guided the team during the design process and helped avoid possible issues in the design of the new platform. Many backup plans were created if one or more of the systems on board had failed. This included but is not limited to considerations of failure in power distribution, leaks, sensor failure, and software.

II. Vehicle Design

Software

Software is a crucial component of an AUV. The team's goal was to perfect a basic system of vision detection before integrating more complex sensors and the accompanying software. The main tool for vision detection used was a neural network trained in TensorFlow. The team developed a Google Colab notebook as it has many advantages. Google Colab is a cloud-based Python development environment that allows users to train on Google's cloud-based GPU's [1]. This allowed the team to train more efficiently. The completely cloud-based system guarantees that the team can train the network anywhere in the world where an internet connection is available. Other advantages that Colab provides is the general ease of use. Previously, the team had to run multiple scripts in order to train a network. With Colab, all the scripts can be placed into one notebook, allowing anyone to train a network with the click of a button after the dataset has been labelled. During initial experimentation with Colab, the team found that training was done 4-5 times faster than the training being done on the machine available to them.

Electrical

With a custom AUV design, it was determined that a custom power board was also necessary. Its purpose is to handle the miscellaneous tasks on board the AUV, such as emergency shutoff, leak detection, voltage regulation, and power management. It uses an Mbed NXP LPC1768 as the main processor due to its native ethernet capabilities and ease of use. This allows the main software to easily communicate with the power board and for the power board to gracefully shutdown the onboard computers before disconnecting the batteries. It also relays information about the state of the AUV and allows the power board to control the internal RGB LEDs, which provides information to the team during a competition run. The ethernet is also used for the remote software emergency stop, a system which cannot override the physical estop switch for safety. Lastly, the power board monitors the internal environment, such as temperature and humidity, to control onboard recirculation fans. Various leak sensors placed in multiple areas in the AUV sense when there is a leak and activate a single use kill switch which cannot be reactivated unless the main batteries are physically disconnected.

Designing a custom power board allowed the team to implement many features into a small footprint. While designing it the team had to consider many things such as budget limitations, size constraints, and reliability. The size constraints were the most difficult part because there are four large voltage regulators that produces a large amount of heat. This meant that the four large voltage regulators needed to be flush against the aluminum frame to dissipate heat. This coupled with the many features that were needed such as having a small footprint and the layer constraints on the PCB. Designing the board was a difficult task, but a necessary one.

Currently the ESCs are controlled by an Arduino Mega instead of a custom motor controller due to the amount of work required to design the custom power board. In the future, a custom motor controller will be designed to replace the Arduino. This season, the team decided to include a DVL for the purposes of data collection. The data will not be actively used for autonomous decisions. The onboard computers consist of an Intel NUC and an NVIDIA Jetson TX2 for vision. The NUC's primary function is to handle controls and any other task on board. However, this season the NUC will be temporarily used for data collection from the DVL instead of its primary function. The on-board cameras are from Leopard Imaging and they communicate with the Jetson over a MIPI interface.

Mechanical

The chassis of the AUV is built around a modular frame consisting of four rails arranged in a rectangle. This design allows the team to add, move, remove, or replace components as needed in order to achieve versatility in sensor configuration and to be able to assemble or disassemble the AUV efficiently. This modularity allows the team to swap sensor configurations in a short period of time. In a competition setting, this can be used to change which tasks will be attempted by the AUV. In the future, if a second identical platform was to be built, the sensors and equipment can be interchangeable. Allowing for many different competition strategies, as well as an additional backup in the case of equipment failure. In order to achieve this configurability, the frame of the AUV is designed with a large hollow area under the main electronics enclosure to allow ample space for both current and future systems. Such as but not limited to sonar, DVL, dropper, downward facing camera, etc.

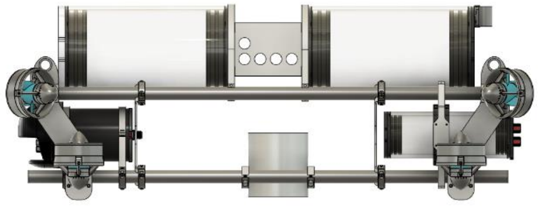

Figure 1: Ample room has been designed underneath the electronics enclosure in order to facilitate any future equipment. Having heavy equipment on the bottom ensures that the AUV is statically buoyant.

The decision to create a modular AUV resulted in the use of Fischer Core Series connectors. The use of these connectors gives the team the ability to completely remove the primary electronics enclosure from the main chassis of the AUV. This provides many advantages such as the ability to ship the chassis separately, swap out electronics enclosures, and work with the enclosure separately from the chassis for repairs and maintenance. These rugged connectors also allow the team to easily swap out parts such as the thrusters or sensors in the event of a failure. In addition, to the Fisher connectors, we make use of a SEACON connector for its wet mate ability to use on our tether. Without these connectors, the modular design of the AUV would not be possible.

III. Experimental Results

Delays in manufacturing and COVID-19 made testing difficult for the team. Regardless, the team did everything in their power to test various systems of the AUV. While many of the parts were being manufactured, the software team began to test vision using a dataset of glasses. Many pictures of people wearing glasses were pulled from Google and used to train a network using TensorFlow. There was a confidence rate that was consistently above 80% using this method. This was used as a control for the vision portion of the AUV. Plans were made to reproduce the competition elements such as the gate and buoy to train the network, but the shutdown of the state due to COVID made this impossible. Leak testing with the electronics enclosure was performed days before the lockdown and was very successful. The enclosure was held underwater for roughly 5 minutes at a time and checked for leaks. After 20-30 minutes, it was determined that the enclosure did not have any leaks.

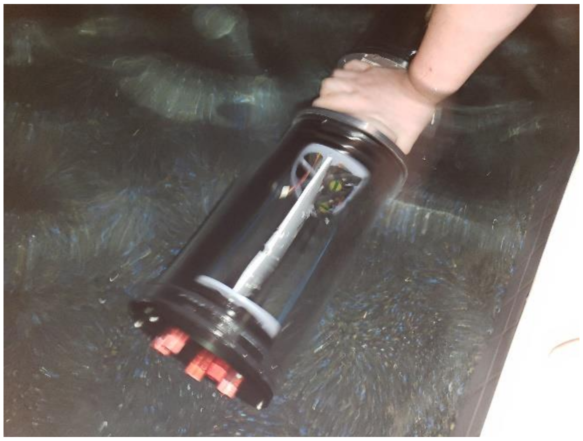

Figure 2: The electronics enclosure was leak tested separately from the rest of the chassis. It was pushed down under the surface of the water and monitored for any potential leaks.

IV. Acknowledgements

The team would like to thank our faculty advisors, Dr. Brian Butka, Dr. Christopher Hockley, Dr. Eric Coyle, Dr. Patrick Currier. As well as various upper classmen and graduate students including Stephen Cronin, Casey Troxler, Matthew Helms, and DJ Thompson for their advice and direction. A special thank you to Mr. Bill Russo and the Embry-Riddle Machine Shop for always getting our parts to us as soon as they could, and Mr. Michael Potash for electrical design advice. The team would also like to thank Embry-Riddle's College of Engineering and the Mechanical Engineering department for their long-term support of the project.

V. References

[1] *Google Colab.* (2020). Google. [Online]. Available: https://colab.research.google.com/

VI. Appendix A: Component Specifications

Component	**Vendor**	**Model/Type**	**Cost (if new)**
Buoyancy Control	Blue Robotics	Subsea Buoyancy Foam	N/A
Frame	Custom Design		
Waterproof Housing	Blue Robotics	6" Series Watertight Enclosure	$560.00
Waterproof Connectors	Fischer Core Series Connectors	Alu-Lite	TBD
Thrusters	Blue Robotics	T200	$206.00 Each
Motor Control	Blue Robotics	Basic ESC	$27.00 Each
High Level Control	Arduino	Mega	$38.95
Battery	TBD		
Converter	VICOR	Micro Family	$177.55
Regulator	muRata	UWE Series	$73.00
CPU	Intel	NUC NUC717DNBE	~$700
Internal Comm Network	NETGEAR	8-Port PoE Switch	$69.99
Programming Language 1	Python 3		
Programming Language 2	C++		
Compass	VectorNav	VN100	$800.00
Inertial Measurement Unit (IMU)	VectorNav	VN100	$800.00
Sonar	Blueview	M900	~45-50k
Doppler Velocity Log (DVL)	Nortek	DVL 1000	~$18k
Camera(s)	Leopard Imaging	LI-IMX477-MIPI-M12	$279.00
Algorithms: Vision	TensorFlow		
Algorithms: Autonomy	Custom scripts using ROS integration		
Open Source Software	TensorFlow, ROS		
Team Size	Roughly 10 Members		
HW/SW expertise ratio	Roughly 2:1		
Testing Time: In-Water	<2 Hours due to COVID		