SDSU Mechatronics 2018 AUV Vehicle: Perseverance

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ABSTRACT - Perseverance is the Mechatronics AUV for the 2018 Robonation Robosub competition. The main goal for the team was to make a modular design that would eventually be able to compete all obstacles but still let us focus on certain tasks. This strategic decision guided the design efforts, leading to a mechanical design with swappable components, a generalized electrical system capable of accepting any printed circuit board with a common interface, and ample opportunity for future expansion.

I. INTRODUCTION

Mechatronics is a student-run organization affiliated with San Diego State University(SDSU) that is composed of over 30 undergraduate student members. Over the years, we have developed four vehicles: three autonomous underwater vehicles (AUVs) and one unmanned aerial vehicle.

Our goal is to provide a hands-on learning experience to students while developing new autonomous systems. This year, we have focused on improving the system and increasing testing time for the AUV.

A. *Existing Work*

Mechatronics has made three AUVs: Endeavour, Defiance, and Perseverance. These previous vehicles have provided heaps of experience and information for our latest design.

For the software team, most of the Graphical User Interface(GUI) and mission algorithms were written between last year and this year. The embedded systems interface code was also improved. However, there were many lessons learned from the years before that heavily influenced this year's software such as having an easy way to manipulate variables without having to hardcode them.

The electrical team built off the concept of previous vehicles using a backplane, daughter cards, and a primary computer. This year we made an active backplane, or motherboard, based on the previous design.

The mechanical team also learned from the mistakes of past designs and improved upon important features in Perseverance such as modularity and accessibility. To make the AUV more expendable, we included diverse mounting points on the external and belly frame. To increase accessibility, we implemented a single clamshell seal to easily access all internal components.

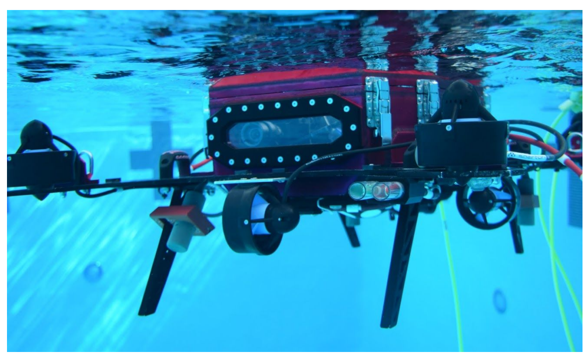

Fig. 1: Perseverance being tested at the SDSU pool.

B. *New Features and Improvements*

For Perseverance's software system, improvements include the implementation of neural networks for better object detection as well as more advancements to the computer vision algorithm. The user interface has also been revamped to make controlling the AUV more user friendly.

New electrical features for the vehicle include a new primary communication protocol, CAN bus, as well as a new secondary communication protocol, I2C.

The mechanical aspects of Perseverance are a complete overhaul of previous designs. Learning from restrictions of tubular cramped enclosures, tightly toleranced radial seals, permanent cable passthroughs and asymmetric overall layout, the new design aimed to learn from these lessons. New features of the mechanical systems include implementation of pneumatics for all actuation, plate aluminum construction with minimal machining, protective modular external frame, standardized fasteners for entire design, a single main seal, swappable IO panels for all cable pass throughs and large top viewing windows.

Fig. 2: Final CAD of Perseverance

II. COMPETITION STRATEGY

Based on previous finalists' runs, it was decided that all tasks except for the manipulation-related tasks would be attempted as fast as possible to get a time bonus like when we won in 2015. In order to make a complex system capable of doing many tasks, the vehicle was designed and fabricated for the 2017 competition with the knowledge that little time would be left for testing, but with plans to make improvements and significantly increased testing this year.

Both the mechanical and electrical architectures were designed with modularity in mind, knowing that not everything would be added at once. This included swappable Input-Output panels on the sides and the back of the vehicles, as well as a motherboard with standardized slots for printed circuit boards we designed. These decisions allowed us to make improvements and fixes this year with minor cost and time requirements. No complex parts were added this year so we could concentrate on testing and reliability.

III. DESIGN CREATIVITY

For the overall design of the AUV vehicle and its systems, the focus was on simplicity, accessibility, and modularity. We found that focusing on these aspects made the design more efficient for testing and debugging purposes.

A. Mechanical Systems

Learning from previous vehicle designs, Perseverance incorporates a clamshell lid design along with a single main O-ring seal, created by welding watejetted aluminum panels together. This design increases the internal volume allowing a sufficient amount of space for the electrical system. The symmetrical design facilitated the buoyancy control of the AUV by keeping the center of gravity close to the center of Perseverance.

A unique design feature that the AUV includes is swappable Input-Output panels for all cable pass throughs, which make it easy to accommodate future sensors.

Another inclusion of modularity in the AUV's design is the variety of mounting points for payloads and external sensors. The main location for mounting is the external frame, which also serves as protection against impact. There is also an exterior frame at the belly of Perseverance that houses most of the pneumatic system. Both frames include mounting slots designed for our standardized fasteners.

An internal frame was redesigned this year to facilitate cable management while maintaining accessibility to internal components and maximizing space. Perseverance's large top viewing windows also make debugging easier when the AUV is undergoing underwater testing.

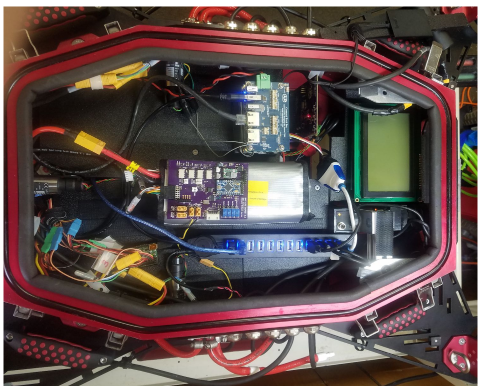

Fig. 3: Perseverance's internal components.

B. Electrical Systems

Our electrical system is made up of six custom boards designed by our members: Weapons Control Board (WCB), Sensor Interface Board (SIB), Battery Management System (BMS), Hydras, Pneumatics Interface Board (PIB), and the Motherboard. All daughter cards connect to the Motherboard through DBUS connectors, which allow us to make new boards with different functionality and capabilities, while incorporating them into the current system seamlessly.

All of our custom boards communicate via CAN Bus. We decided to use CAN because of its ability to support a large amount of devices and messages. CAN also only requires two signal lines for communication which allows for minimal wire management. The main processor, the Tegra X2, then communicates with all the boards through CAN, simplifying our interfacing with the embedded systems.

C. Software Systems

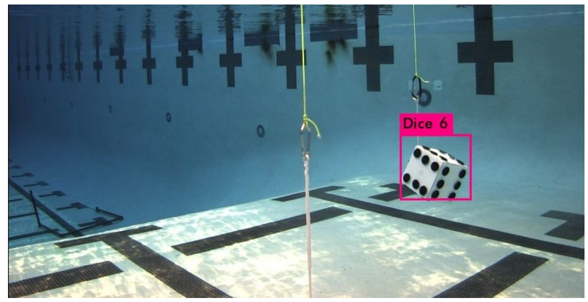

Fig. 4: Computer vision recognizing a dice for the buoy mission.

Our software system is completely written by our members in Python. The software consists of a GUI which allows us to modify the submarine's mission and waypoints. It can be instructed to perform an autonomous system check, which involves testing thrusters and sensors.

Fig. 5: The GUI for the RoboSub competition.

While every mission is fully programmed, there are still a few user variables that can be changed on the spot. These user variables are used to select different mission behaviours without having to reprogram the vehicle. For example, we can quickly tell a mission to either move 5 feet away from the torpedo board for shooting, or telling the sub to go through the Red or Black part of the entry gate.

We have also implemented a You Only Look Once [1] algorithm using a darknet neural network that is able to be used effectively due to the Tegra X2 processor.

IV. EXPERIMENTAL RESULTS

This year, we had the most amount of testing done for a RoboSub vehicle, which was a total of 100 hours to date. With this amount of testing, we were able to refine our computer vision and mission algorithms.

We have currently tested five major aspects of the vehicle: PID Control, Waypoint Navigation, Qualifying Mission, Dice Mission, and Gate Mission.

PID stands for Proportional-Integral-Derivative which is a frequency-based controller. PIDs are the first part of the vehicle we test and iron out since we need the control systems to be working before testing any other aspect of the vehicle. PID testing involves telling the AUV to hold a specific orientation and position and monitoring how quickly it is able to reach that desired location. We then adjust the values of the controller until we get the behaviour we desire. We also test disturbance rejection by having our swimmers forcefully move the AUV away from its desired location to see how it reacts.

After PIDs have been properly tuned for the vehicle, we started testing mission code. The first mission we tested was the dice mission. The AUV has been able to identify the dice using the computer vision processes and has successfully hit it in succession.

The vehicle has also completed the Qualifying Mission successfully and we have uploaded a video of the performance to pre-qualify.

We are currently in the process of testing the entry gate. The AUV is nearly capable of going through the gate and we hope to have this mission finished very soon. After this mission is completed, we hope to complete the torpedo mission, path mission, and roulette wheel mission.

In order to test our electrical system, we have designed an "electronics test-fixture". This test-fixture allows our electrical members to program and test their custom PCBs outside of the vehicle. By having a test-fixture, we can quickly identify bugs with the embedded code or with the circuit design. In previous years, the PCBs had to be tested directly in the AUV which made it very difficult to find the sources of issues.

Additionally, we confirm watertight integrity of the AUV by performing a vacuum test each time seals are broken on the vehicle.

IV. ACKNOWLEDGMENTS

The Mechatronics team would like to thank the SDSU Engineering Department, Northrop Grumman, Matlab, Metal Masters, Amazon, McMaster-Carr, and Altium.

A big thank you especially to our faculty advisor Theresa Garcia, as well as Donovan Geiger and the late Dean Mehrabadi who always supported and believed in us.

VI. REFERENCES

[1] J. Redmon and A. Farhadi, *YOLOv3: An Incremental Improvement*. Washington: University of Washington, 2018.

Appendix A: Component Specifications

Component	**Vendor**	**Model/Type**	**Specs**	**Cost(if New)**
Buoyancy Control	PVC Pods			
Frame	Custom 6061 T6 anodized aluminum, 0.25" Thickness			
Waterproof Housing	Custom 6061 T6 anodized aluminum, 0.25" and 0.5" Thickness			
Waterproof Connectors	Seacon	WET-CON		$300
Thrusters	Blue Robotics	T200		$169
Motor Control	Hobby King	Afro 30A Race Spec	30 amp	$13.69
High Level Control	NVIDIA	Jetson Tegra X2		$599
Actuators	None			
Propellers	Blue Robotics	T200		$169
Battery	Hobby King	Lipo Battery	16000 mAh 4s 10c Multistar	$101.37
Converter	None			
Regulator	Mini-Box	DCDC-USB		$54.95
CPU	NVIDIA	Jetson Tegra X2		$599
Internal Comm Network	Custom			
External Comm Interface	Seacon	Seacon Cable		$1000
Programming Language 1	Python			
Programming Language 2	C++			
Compass	Sparton	AHRS 6E		$1500
Inertial Measurement Unit (IMU)	Sparton	AHRS 6E		$1500

Doppler Velocity Log	Nortek	DVL1000		$18000
Cameras	Point Grey	BFLY-U3	Resolution: 808x608	$325
Hydrophones	Sparton	PHOD1		$999
Manipulator	None			
Algorithms: vision	You Only Look Once V3			
Algorithms: acoustics	Time Difference			
Algorithms: localization and mapping	DVL			
Algorithms: autonomy	PID			
Open source software	OpenCV			
Team size	32			
HW/SW expertise ratio	1.5			
Testing time: simulation	0			
Testing time: in-water	100 Hours			

Appendix B: Outreach Activities

Mechatronics is proud to be a part of STEM outreach. This year, we increased the variety of events that we attend. We went to the Girls Inspiring Real Leadership and STEM (G.I.R.L.S.) conference hosted at Eastlake High School, where we interacted with young women and showcased our RoboSub vehicle to spark interest in the STEM field.

Fig. 6: G.I.R.L.S. conference exhibition.

Other exhibitions include showcasing our AUVs at the Fleet Maintenance and Modernization Symposium organized by the American Society of Naval Engineers, as well as participating in the San Diego Winter STEAM Maker Festival, where we demonstrated how we use 3D printing to prototype for our RoboSub vehicle to young children.

Mechatronics also had a Los Angeles STEM high school tour the team's facilities and the SDSU Engineering building. The students got an up-close look at our RoboSub projects and learned about our organization.

Fig. 7: Students tour Mechatronics HQ.

Our team also presented on the design of our RoboSub vehicle Perseverance at a San Diego Chapter meeting of Marine Technology Society, as well as at the AUVSI Xponential exhibition.

Fig. 8: AUVSI Xponential presentation.

We also were part of the opening of SDSU's new Engineering Interdisciplinary Sciences building and were featured on the event's Facebook live stream.

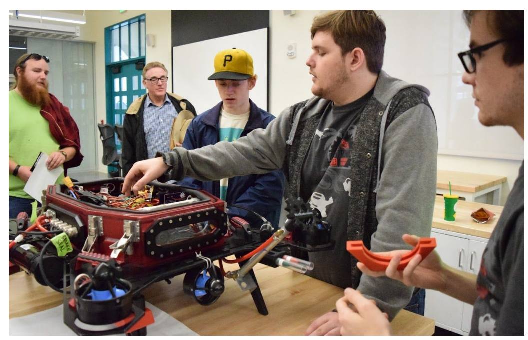

Fig. 9: Incoming SDSU students learn about RoboSub.