BeaverAUV: Technical Report of the Buffy AUV

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Abstract

Abstract—Buffy is BeaverAUV's submission to the 2019 RoboSub Competition. The AUV (Autonomous Underwater Vehicle) was designed and built by a small team of high school students from Beaver Country Day School. It was designed as an iterative improvement over the previous Prospero Mark II AUV. While maintaining many of the same similar design concepts as the Prospero Mark II AUV, Buffy features key design improvements to the usability, modularity, robustness, and functionality of the robot. The design was focused on creating a versatile, agile robot with functionality specialized for the RoboSub competition. Buffy was developed to be a fully functional robot with the capability of completing all RoboSub obstacles, while still being cost-effective to manufacture. This journal paper describes how BeaverAUV designed Buffy to accomplish these goals.

Design Strategy

Being a high school team, BeaverAUV's team includes students with different levels of robotics knowledge. As a result, BeaverAUV's design strategy attempts to balance competition task performance with program management; primarily new member induction and upskilling. Time is split between developing the robot and trying to build a robust program that encourages the pursuit of engineering. This program AUV is a real-world experience that teaches students how to code, design, predict, collaborate and test. New members of the team learn rudimentary and more advanced subjects, such as the basics of electricity, tolerancing, basic fabrication, and machine learning-- all through building the submarine. This also allows for better Team Morale as mentorship and mutual respect forms between new and returning members through the transfer of knowledge.

The competition performance goal is to earn points by crossing through the smaller portion of the gate, using OpenCV to identify and follow the path, then use an electromagnetically propelled torpedo to slay vampires. With an improved lightweight design of this year's submarine "Buffy", the AUV remains in the smallest brackets for both size and weight while allowing for new attachments.

Vehicle Design

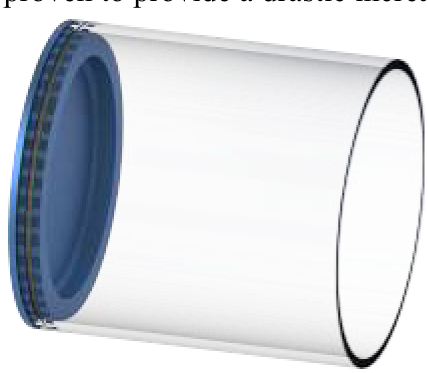
Mechanical Design

1. *The frame.*

Due to fabrication costs, the frame of the AUV remains unchanged from 2018. However, the computers and power system have been reduced to a fraction of their original size. This makes buoyancy a bigger issue. The pressure hull was shortened on one side which allows for the main hull to encapsulate all critical systems with reduced air space. With space and weight saved, we are able to fit in additional components, such as a "coil gun" style electromagnetic torpedo launcher and a new camera that is in line with the central axis.

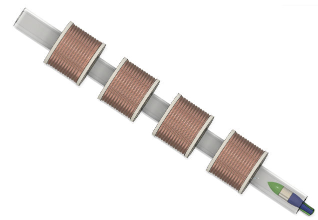
2. Hulls & End Caps

Two 7.5” ID x 8” OD acrylic tubes serve as Buffy’s main hull. These tubes form axial O-ring seals with both the center console and two custom aluminum end caps. The end caps were designed to remain permanently in one side of each hull. The hull and end cap assemblies can be removed and replaced without disconnecting any electronics or removing any screws. This has proven to provide a drastic increase to usability.



3. *The Central Hub*

. The machine revolves around a central hub manufactured out of machined aluminum pipes and blocks. Cost and manufacturing efficiency were of priority when deciding whether or not to make them ourselves or have them ordered. Sending them out for fabrication proved to be too costly. Instead, the AUV is comprised of stock components minimally machined, welded together.



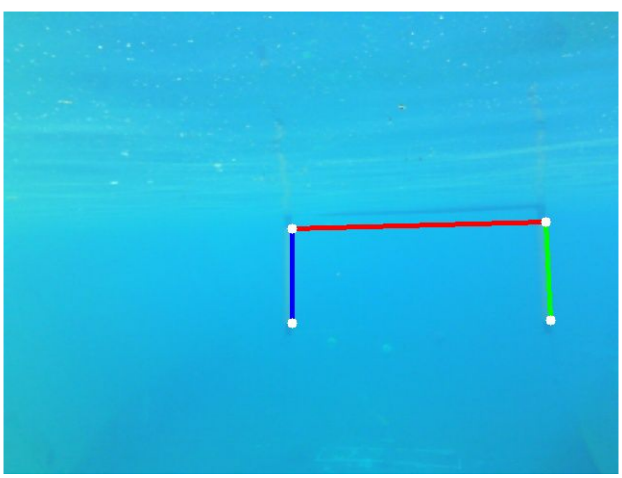
4. Electro-magnetic Torpedo Gun

This year the team has taken on the challenge of creating a new system for the torpedo launch. Although most teams take a pneumatic approach of using pressurized air, we considered that design too big of a risk given the pressurized hull and end cap design. Alternatively, solenoids could be placed in the hull, however, any failure would result in the end caps being blown off and water flooding the hull causing catastrophic damage. Instead, an innovative system to electromagnetically propel the torpedo through a coilgun was designed. This allows complete avoidance of pneumatics, as well as allows the reuse of the electronic system, and takes advantage of the high current abilities of LiPo batteries. Magnets embedded in the torpedo interfere with the opposite magnetic field created by the current in the wires and propel it. Furthermore, we’ve embedded magnets into the torpedo by placing a ferrous material on the end of the coilgun, which makes sure the torpedo can be securely held in place while the AUV completes other tasks without the need for creating over-engineered retention systems with more room for error.

Electrical Design

This year, the electrical system has been completely renovated. Bulky power regulators were replaced by a custom PCB, designed in house. ESC placement was redesigned to reduce space. This brings up a thermal concern, but in their new location, the ESCs sit next to the aluminum hull which is essentially a giant heatsink.

The computers also went underwent a major redesign. Evolution to date includes the transfer from an entire desktop computer with a custom mount, to an NVIDIA Jetson TX2 with the default development board, to this year's design which is a Jetson TX2 with a custom carrier board. Each change reduced the size, weight, and power requirement (which was the main factor in downsizing the power regulator). Additionally, some of the other components such as the network switch and Raspberry Pi have been traded out for smaller, more efficient versions. To top it off, the actual chassis that holds them together was redesigned to essentially create a computer "sandwich" that efficiently holds all the components while giving the heat producing parts access to airflow and the aluminum hull heatsink.



Software Design

This year the code design features image recognition/object detection, re-vamped thruster control, a PID manager, a state machine run on Jetson, and ROS technology which allows for communication between different interfaces. This year's code uses OpenCV to recognize image geometry. A USB camera is used to collect image data, which is then run through OpenCV image filters that will then allow it to detect objects in the image. The focus of the filters is primarily based on the R and G channels because unlike blue, these colors do not blend in with the water. From there, the state machine deciphers where the object needs to be directed to next. The focus on the thruster control algorithm centers mostly around figuring out how to achieve the most efficient movement autonomously. The algorithms run on the NVIDIA Jetson TX2.Motor values are first sent to the Arduino Nano, which tells the ESCs what percentage to run the motors at, and finally, the data is transferred to the motors. This year's PID manager references the depth sensor and uses an I2C protocol through a Raspberry Pi. The use of ROS allows for communication to occur between interfaces and enable automation.

Experimental Results

This year experimental designs have been a key part of the process of preparing the AUV. These designs span all the way from switching to OpenCV to creating a new electromagnetic torpedo gun. The gun provides a way for Buffy to precisely control the projectile's velocity through using the micro-controller and is completely electronic. In theory, the torpedo launcher is very simple, one loop of the circuit only contains an LED, a coil, a transistor, a microcontroller, and a battery. The circuit works by opening the transistor and allowing the current to flow into the coil, which creates a magnetic field, that can predict using the Right-Hand Rules, and then closing the transistor and have the remaining voltage drain in the LED. By using an Arduino Nano as the microcontroller the AUV is limited to using 12 coils at maximum (because there are only 12 ports), but it only needs to use around ten. The torpedo itself has magnets built into its hull and when the magnetic field is turned on it is propelled out of the barrel.

Buffy also features ROV mode which allows it to be controlled manually via a joystick for experimental testing.

Acknowledgments

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References

[1] Eduard Hiti. "Macho - C++ Machine Objects". In: (2007).
[2] Shaoqing Ren et al. "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks". In: (2015)

APPENDIX A: Expectations

Subjective Measures			
	Maximum Points	*Expected Points*	*Points Scored*
Utility of team website	50	40	
Technical Merit (from journal paper)	150	130	
Written Style (from journal paper)	50	40	
Capability for Autonomous Behavior (static judging)	100	70	
Creativity in System Design (static judging)	100	80	
Team Uniform (static judging)	10	8	
Team Video	50	38	
Pre-Qualifying Video	100	0	
Discretionary points (static judging)	40	15	
Total	650	421	
Performance Measures			
	Maximum Points	*Expected Points*	*Points Scored*
Weight	See Table 1 / Vehicle	42	
Marker/Torpedo overweight or size by <10%	minus 500 / marker	0	
Gate: Pass through	100	100	
Gate: Maintain fixed heading	150	150	
Gate: Coin Flip	300	300	
Gate: Pass through 60% section	200	0	
Gate: Pass through 40% section	400	400	
Gate: Style	+100 (800 max)	100	
Collect Pickup: Crucifix, Garlic	400 / object	0	
Follow the “Path” (2 total)	100 / segment	200	
Slay Vampires: Any, Called	300, 600	0	
Drop Garlic: Open, Closed	700, 1000 / marker (2 + pickup)	0	
Drop Garlic: Move Arm	400	0	
Stake through Heart: Open Oval, Cover Oval, Sm Heart	800, 1000, 1200 / torpedo (max 2)	0	
Stake through Heart: Move lever	400	0	

Stake through Heart: Bonus - Cover Oval, Sm Heart	500	0	
Expose to Sunlight: Surface in Area	1000	0	
Expose to Sunlight: Surface with object	400 / object	0	
Expose to Sunlight: Open coffin	400	0	
Expose to Sunlight: Drop Pickup	200 / object (Crucifix only)	0	
Random Pinger first task	500	0	
Random Pinger second task	1500	0	
Inter-vehicle Communication	1000	0	
Finish the mission with T minutes (whole + factional)	Tx1000	0	
Total		1292	

APPENDIX B: Components

Component	**Vendor**	**Model/Type**	**Specs**	**Cost (if new)**
Buoyancy Control	Made in Shop	n/a	Custom	n/a
Frame	Local Maker	n/a	aluminum	In Kind Donation
Waterproof Housing	Acrylic Tube	n/a	acrylic	$200
Waterproof Connectors	Blue Robotics	M10	Cable Penetrator for 4-5mm Cable	$4
Thrusters	Blue Robotics	T100, T200	Brushless and Thruster	$119/$169
Motor Control	Blue Robotics	ESCs	included	included
High Level Control	BeaverAUV	custom	R Linear Least Square PID	n/a
Propellers	n/a	n/a	n/a	n/a
Battery	Hobby King	Turnigy	16000MAH 4S 12C	$137.92
Converter	Seacon	unknown	wet/dry connector	$50
Regulator	SynQor	NQ20x20QGx40	20V ib 20 V out 40 A	
CPU	Nvidia	Jetson TX2	Dual-Core NVIDIA Denver 2 64-Bit CPU Quad-Core ARM® Cortex®-A57 MPCore	$299

Internal Comm Network	Generic Network Switch	n/a	n/a	n/a
External Comm Interface	Seacon	MCIL4m	wet/dry connector	$50
Programming Language 1	Python			
Programming Language 2	C++			
IMU	VectorNav	VN-100T Rugged Dev Kit		$800
DVL	n/a			
Camera(s)	Microsoft LifeCam (2)	Cinema HD	720 p	$30
Hydrophones	n/a			
Coil Gun	Built in House			n/a
Open source software	ROS, OpenCV			
Team Size	15			
HW/SW expertise ration	0/0*	*High School Team		
Testing time: simulation	20 hours			
Testing time: in-water	6 hours			