BeaverAUV: Technical Design Report of Tuolomee AUV

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***Abstract*—Tuolomee is BeaverAUV's submission to the 2020 RoboSub Competition. The AUV was designed and built by a team of high school students from Beaver Country Day School. Tuolomee was designed as an iterative improvement over last year's Buffy AUV, making key improvements in the accessibility and functionality of the vehicle. Additionally, several logistical advancements were made, including sponsor relations, outreach, and team function among the COVID-19 Pandemic.**

Competition Strategy

Being a high school team, BeaverAUV's team includes students with different levels of robotics knowledge. As a result, BeaverAUV's competitive strategy has attempted to balance competition task performance with program management, primarily that aimed towards the cultivation of members' talents. To this end, time is split between technical endeavours and the development of robust programming that encourages the pursuit of engineering. With the onset of the COVID-19 pandemic, greater time has been allocated to towards these programming aspects, accelerating the typical pipeline of team members (i.e., learning rudimentary skills such as coding principles and circuit construction and progressing towards more advanced topics such as CAD and object detection). This progression and its recently accelerated pace have offered another point of learning, as senior members have been able to shift focus from demanding technical endeavours and practice leadership and mentorship while transferring knowledge to new members.

Although the in-person portion of RoboSub has been canceled and focuses have shifted accordingly, BeaverAUV is continuing to build towards the future, working towards a vehicle capable of completing tasks using computer vision and torpedo launching.

Vehicle Design

Mechanical Design

1. The Frame

Despite a finished design for a new frame, the frame of the AUV remains unchanged from 2018 due to fabrication costs. However, the reused nature of the frame has not inhibited continued iteration.

The frame, made of ¼ inch anodized aluminum and designed with modularity as a focus, has built in rails for "on-the-fly" weight adjustment and using 3D-printed clips, a series of attachments are fixed to the frame, such as a "coil gun" style electromagnetic torpedo launcher and a camera mount for the both forward and downward facing cameras.

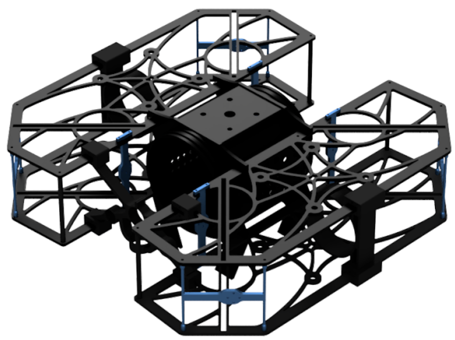

Fig. 1: Tuolomee's frame with 3D-printed attachments.

***2.** Hull*

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, which has proven to provide a drastic increase to usability. When in use, the hull is pressurized.

Fig. 2: 7.5" ID x 8" OD acrylic tube and aluminum end cap assembled.

***3.** The Central Hub*

The machine revolves around a central hub. The central hub consists of minimally-machined stock aluminum pipes and blocks welded together to ensure cost and manufacturing efficiency. Using several hole penetrators and a single wet connector for the tether, all data flows into (i.e., sensor data and external computer input) and out of (i.e., thruster data) the vehicle from the central hub.

Fig. 3: The central hub with hole penetrators attached.

4. *Electromagnetic Torpedo Launcher*

Utilizing a strong electric pulse, magnetic torpedoes can be launched reliably and accurately. Magnets embedded in the torpedo interfere with the opposite magnetic field created by the current in a solenoid and propel it. When not in use, ferrous material on the end of the launcher securely holds the torpedo in place while the AUV completes other tasks without the need for the coil to stay energized. The launcher easily integrates with AUV's design, attaching to the frame using a 3D-printed mount, seamlessly joining our electrical system, and taking advantage of the high current abilities of the LiPo batteries.

Not only does this design have a number of advantages in and of itself, but there are significant advantages over alternate designs. Many teams take a pneumatic approach to torpedo launching. We considered that design too big of a risk given the pressurized nature of a pneumatic system and the AUV's hull. Similarly, additional disadvantages exist for specific pneumatic designs. Solenoid valves can be placed in the pneumatic tank, however, such a design is difficult to manufacture. Alternatively, solenoid valves could be placed in the hull, which increases the risk of catastrophic failure.

Electrical Design

This year, efficiency and reliability were emphasized with changes in the electrical system. For instance, our external terminals were replaced with "wet sockets" to increase efficiency and to improve the long term life of the AUV. This and other minor alterations allowed for greater accessibility and modularity of the AUV's pre-existing electrical system. This pre-existing electrical system was composed of two primary modules: the power and computer.

The power module is driven by a custom PCB, designed in-house. This PCB and an attached Arduino Nano drive eight ESC's placed on a custom acrylic rack to ensure organization and compactness. This compactness raises a thermal concern, but in their location, the ESC's sit next to the aluminum hull, essentially acting as a heatsink.

The computer module is centered around a network switch, which interlinks the on-board NVIDIA Jetson TX2, on-board Raspberry Pi, and any external computer.

Both modules are held by a chassis designed to create a computer “sandwich”, effectively holding all the components while giving the heat-producing parts access to airflow and the aluminum hull heatsink.

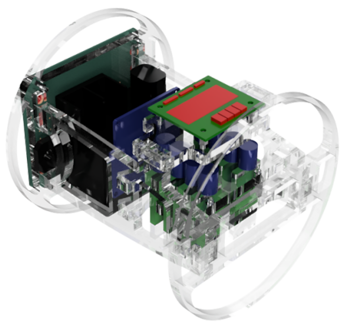

Fig. 4: The power module assembly.

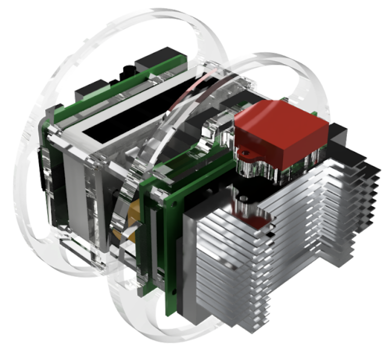

Fig. 5: The computer module assembly.

Software Design

Using ROS for interprocess communication, the AUV’s software centers around two core processes: mission control and thruster control.

Mission control centers around a state machine for task management. Using OpenCV, images collected by a USB camera are filtered, focusing on the R and G channels. Once filtered, image geometries are recognized and the desired object is detected. Then, the state machine determines what actions must be made based on the desired object’s location.

In response to the actions determined by the state machine, thruster control decides the most efficient movement to achieve these actions. Once decided, motor values are sent to the Arduino Nano, which tells the ESC’s at what percentage to run the motors, and the data is transferred to the motors. A PID manager is used to update these data and maintain the desired movement and position. Additionally, the data from the waterflow sensors gives an indication of the velocity of the AUV. This data is transmitted to the PID manager as well.

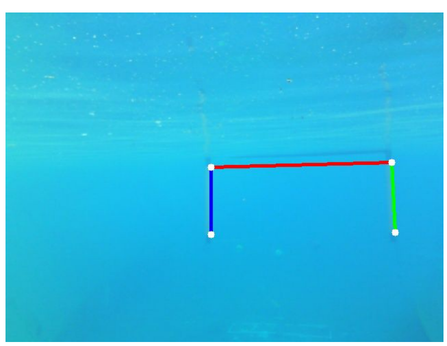

Fig. 6: Gate detection on image previously collected at TRANSDEC.

Experimental Results

This year, diverse experimentation has played a key part in the design process. Most notable are those initiatives that have allowed for experimentation despite the COVID-19 pandemic and resulting geographical separation of our team. Through virtual collaboration (e.g., weekly team video meetings and continuous written correspondence), required social distancing has been flipped as an advantage, as it has allowed team members to use increased personal time to experiment more boldly. For instance, as it comes to continued visual development, team members have simultaneously experimented with a variety of methods (e.g. image filtering and line detection, deep learning, etc.) using data collected in prior competitions, allowing for decisions upon performance and reliability to be made without the AUV in the water. Additionally, despite the inability to access the AUV and BeaverAUV's workspace, team members have been able to continue electrical develop by reproducing the AUV's electrical system with hobby parts and sparse pieces of the AUV's actual system that were collected before a hurried, mandatory separation from our physical space. Remote exploration has also allowed new and experienced members alike to discover personal methods of individual research which expands our horizons as students, engineers, and teammates.

Acknowledgments

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Several sponsors contributed to the BeaverAUV team. The team would like to thank BlueRobotics, MathWorks, Nvidia, Connect Tech Inc., and VectorNav for all of their support and kind donations which have helped to advance the functionality of the AUV.

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: Component Specifications

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			

Appendix B: Outreach Activities

Presentation

During the Fall term of this past academic year, BeaverAUV curated a presentation to the Upper School community at Beaver Country Day School to share their experiences at the 2019 Robosub competition. The presentation consisted of photos, videos, and student testimonies to an audience of over 300 high school students. This presentation was the first step in new member recruitment for the year.

CV Workshop With Matlab

This past Winter BeaverAUV had the honor of taking part in a Matlab workshop conducted by Connell D'Souza. Mr. D'Souza graciously joined us at Beaver Country Day School during a day long workshop. The team practiced computer vision and training using the Matlab software. This workshop was used as a recruiting tool, and several new members joined after attending the workshop.

New Member Recruitment

This year BeaverAUV welcomes seven new members to their team, in the grades 9th and 10th. New members were invited to onboarding events, where they learned the basics of the sub, and were later split into specific groups based on their individual interests.

COVID-19 Workshops

Every member of BeaverAUV worked diligently to adapt to the difficulties presented by the COVID-19 Pandemic. The removal of the in-person competition allowed us to focus more on training members. We held a variety of workshops weekly for the remainder of the school year for a variety of skill levels. These ranged from beginner python tutorials to complex workshops in Open-CV.