Abstract

This technical design report will be an overview of the engineering processes used to construct an underwater ROV capable of performing required tasks. The report will cover the required tasks, describe the design approach to these tasks, summarize experimental results, and describe future plans for the ROV. The report will also cover the development of a coral recognition algorithm hosted on a Google Coral computer that distinguishes between alive and bleached/dead corals.

The construction of the ROV was achieved by following the engineering design process. The engineering design process consisted of identifying a problem, imagining possible solutions, planning the implementation of these solutions, and then creating and testing the solution. This process continues until an effective solution to the problem is found.

The ROV's frame consists of two laser-cut pieces, connected by fiberglass rods. The side motors are built into each laser-cut frame piece, and the up/down motor is in a 3D printed holder suspended from the supporting rods in between the two frame pieces. This design makes it easy to keep the craft streamlined and the center of mass in the center of the craft. The flotation consists of two pieces of purple insulation foam, towards the top in the front and back of the craft. This insulation foam is very buoyant, and easy to hotwire into the desired shape. The hook consists of a simple fiberglass rod. However, it can be adjusted into three different positions to suit the current task. This is done by having the hook attached to a rotating axle in either frame, and holders in positions along the frame that it can snap into or slide along. The hook can be adjusted to sit along the frame, where it is out of the way during an obstacle course run. It can extend from the frame to act as a standard hook, capable of picking up objects under the water. It can also be snapped into a position where it is angled upwards, and capable of pushing away trash on the surface of the water. This design addresses all tasks required in the obstacle course and challenge course.

A stock SeaPerch was built with a GoPro, capable of taking video and photos underwater. The coral recognition algorithm operates on a dataset of annotated coral images on the online Teachable Machine service. This software is easy for others to access and use in their own SeaPerch projects - others may also build crafts capable of recording underwater, and use the trained algorithm as well.

Task Overview

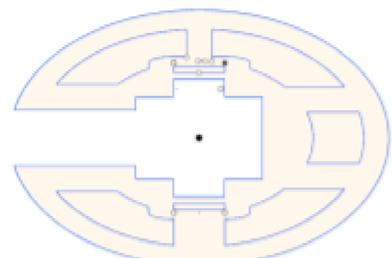
The first task is the obstacle course. This course requires the ROV to travel through five hoops, the surface at the other end of the course, return through the hoops, and finish at its starting point. The ROV must be capable of traveling through this course as quickly as possible, maximizing both horizontal and vertical speed. The ROV design is very small and minimizes weight to maximize speed. The two laser-cut frame pieces on either side of the craft have almost completely sheer faces, meaning the craft is very unlikely to get stuck on a hoop when passing through one. A heavy-duty tether was also used to improve speed by increasing the electricity sent to each motor.

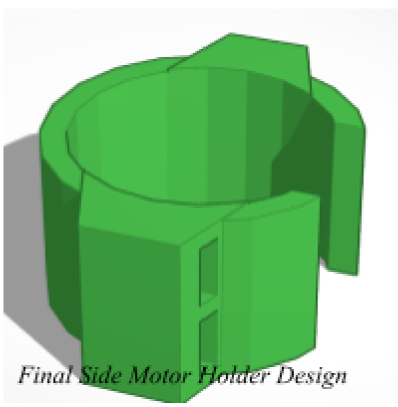
The second task is the challenge course. This course requires the ROV to assist with cleanup efforts in a polluted waterway. This consists of disarming and securing "active" mines, removing floating trash from the water's surface, and disposing of submerged waste in an underwater vault. This variety of tasks requires the ROV to adapt to several different situations, while effectively traversing the course in hopes of achieving a time bonus. The ROV is equipped with an adjustable hook, which can be switched between three different positions depending on what task it is performing. This system consists of a simple fiberglass rod, a rotating axle on which the rod rests, and two different hooking elements that the rod can snap into or slide along. This is mirrored on either set of the craft. One setting allows the craft to either pick up submerged waste, where the rods extend forwards from the bottom of the craft. The other setting allows the craft to push along floating waste, by extending the rods upwards, with a mesh in between to push any waste in between the rods.

Design Approach

Throughout the construction of the ROV, the team used the engineering design processes to assess all tasks the ROV was required to perform. The engineering design process consisted of identifying a problem, imagining possible solutions, planning the implementation of these solutions, and then creating and testing the solution. This process continues until a solution to the problem is found. This process was applied to all design decisions involved in developing the craft.

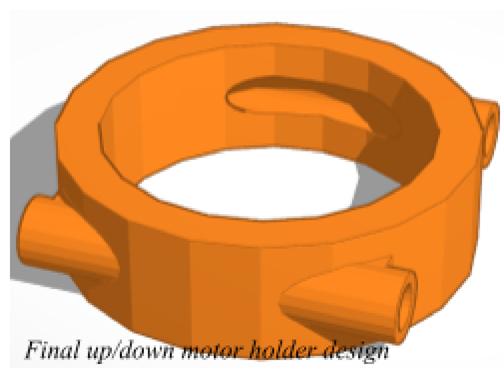
The original design, similar to the final design, consisted of two laser-cut frames, connected by CPVC pipes. The frame needed somewhere for motors, flotation, and a hook element to go. In this design, the side motors would be built into either side of the frame, and the up-down motor along the supporting rods. The flotation would consist of purple insulation foam inserted into the holes of the frame. The hook would be part of a bent wire clothes hanger attached to one of the supporting rods. However, this frame shattered easily, didn't fit the extended motor shaft, and had no way of connecting to the other side of the frame.


Original CAD of ROV frame


Final Side Motor Holder Design

The side motor holders are meant to snap into place on the side of the craft easily, while safely holding the motor. All of our motor holder designs had holes on the top and bottom for zip ties to secure the holder to the craft. Previous iterations were either too small, too big, or too fragile.

The up/down motor holder is suspended from the two central supports. The motor fits snugly inside, pointing downwards. The only previous design was too small, and did not fit the motor.


Final up/down motor holder design

The motors had extended shafts. This had several different benefits; it improved speed, it made the craft more balanced, and gave us more design space to improve the motors. Extended motor shafts improve speed, because they allow the propellers to be further away from the motors, where they may be able to cycle through more water, improving propulsion. Balance is also improved because an extended motor shaft means that the mass of the motors results in the center of mass being central to the craft, while the propellers can still function effectively. This also means that it's easier to design other elements of the craft, such as flotation or the hook, because the moving parts are out of the way and accounted for.

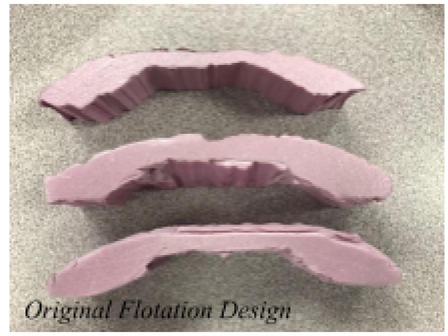

Extended Motor Shaft Clamp

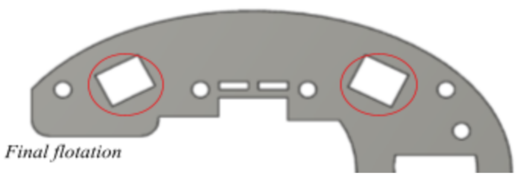

Final Propeller Design

Using 3D printed propellers rather than the stock propellers was considered. The "angle of attack" of the propeller was based on stability and efficiency (Sinha, 2019). Since the stock propeller was already designed with these results in mind in relation to a SeaPerch craft, the angle of attack is identical. Due to balance, 3 blades were used. (Jenkins, 2020). After experimentation with this design, as detailed in the Experimental Results section, it was concluded that the stock propellers are in fact better.

Design Approach Continued

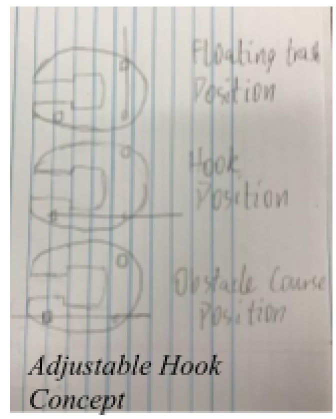
The craft needs to have a center of buoyancy aligned with the center of mass. Effective flotation design is best to achieve this. The flotation consisted of purple insulation foam. This material was chosen primarily for its great positive buoyancy, but also because of how easy it is to manufacture into a certain shape. To the right is an image of our original flotation design, meant to slot into the holes of our first frame design iterations.


Original Flotation Design


Final flotation

Pictured to the left is where the flotation goes in the final design. It extends on either side, from one end to the other. The flotation is attached with superglue. This compact design keeps the craft slightly positively buoyant.

The challenge course posed an important design challenge. It requires the craft to be capable of picking up both submerged waste and floating waste. The ROV is capable of doing so through an adjustable hook system (pictured to the right). It consists of a fiberglass rod, as well as three different points for the rod to snap into or slide along. This is mirrored on either side of the craft, with the fiberglass rods attached by a mesh. This hook system is capable of being in two different positions to score points; one with the rods pointing straight forward to get the submerged trash, and another with the rods pointing upwards to catch and retrieve any floating waste.

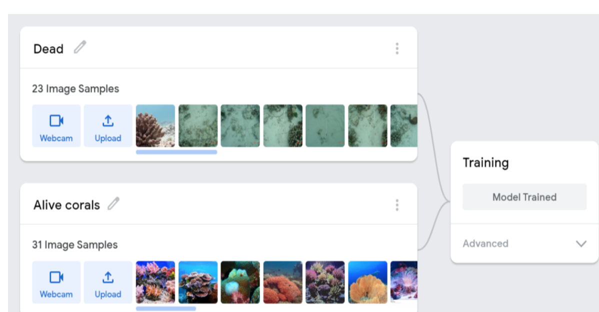


Adjustable Hook Concept


Final Craft Tether

The craft tether was chosen specifically because it is heavy-duty. This novel approach is capable of transmitting more power than a normal ROV tether. There is a tradeoff, however; this tether is quite stiff. This could have an impact on the ROV's maneuverability. This is counteracted by stripping off some of the rubber coatings closer to the craft, and regularly smoothing out any kinks or knots that form in the tether. This has a positive effect on the ROV's speed.

Using Teachable Machine, an online Google service, images of dead and alive coral were analyzed and separated. This algorithm can be used on a large scale by any team with access to the link, and a collection of coral images.



A stock SeaPerch craft was altered slightly to mount a GoPro on it. Using the camera feed from the GoPro, any SeaPerch team can use the online software to record and analyze coral data.

Experimental Results

Trial #	3D Printed Prop	Stock Prop
1	10.9	8.2
2	10.6	8.3
3	10.89	9.1
4	11.23	8.95
5	10.78	7.9
6	11.43	8.2
7	10.36	8.53
8	10.97	8.54
9	10.56	8.2
10	11.16	9.4
11	12.43	9.12
12	11.32	8.76
13	11.62	8.67
14	11.59	9.21
15	11.02	8.67
16	10.98	8.87
17	11.4	8.91
18	11.3	8.9
19	11.33	9.2
20	11.45	7.8
21	11.62	8.34
22	11.42	8.9
23	11.78	8.65
24	11.79	8.77
25	12.55	9.13
26	12.35	7.8
27	11.98	8.45
28	11.83	8.74
29	11.7	8.5
30	11.87	8.4
31	12.28	8.05
32	11.42	9.19
33	12.39	8.92
34	11.38	8.86
35	12.39	7.95
36	12.56	8.6
37	11.99	8.9
38	12.11	7.85
39	11.98	8.23
40	12.12	8.6
Average	11.57075	8.6065


Final tether, coiled up

The method used to find speed comparisons between alternatives was reliable and consistent: A motor was attached to a testing device, which hangs on a fishing line strung across a test pool. The trials were made with the same motor, with consistent battery charge, and along the same distance using an identical testing device.

Tests were made to analyze the impact of 3D printed propellers on the ROV's speed. This was tested by comparing the speed of the stock SeaPerch craft propellers to those that were 3D printed, using a testing device and fishing line. A motor was attached to a testing device, which hangs on a fishing line strung across a test pool. The stock propellers and the 3D printed propellers were tested with 40 trials each, on the same device, with the same motor, over an equal 250 cm length. The results of this experimentation (in seconds) are displayed on the table to the left. It was found that the stock propellers outperformed the 3D printed ones. This prompted stock propellers to be incorporated in the final craft design rather than 3D printed ones.

Tests were also made to see if a heavy-duty tether is superior to the stock craft The speed of the craft was tested with the heavy-duty tether and the standard tether. The stock tether and the heavy duty tether were tested with 40 trials each, on the same device, with the same motor, over an equal 250 cm length. The results of this experimentation (in seconds) are displayed on the table to the right. It was found that, in terms of speed, the heavy-duty tether outperformed the stock tether. This prompted our choice to use a heavy-duty tether rather than a stock one.

Trial #	H.D. Tether	Stock Tether
1	9.2	9.7
2	9.3	9.3
3	8.57	10.1
4	8.75	10.2
5	8.9	9.91
6	8.34	9.4
7	7.9	8.91
8	9.12	8.65
9	9.32	9.1
10	8.5	10.6
11	8.23	9.8
12	7.83	9.7
13	8.34	9.95
14	8.67	9.5
15	8.45	9.6
16	9.1	9.5
17	9.8	10.3
18	8.24	8.96
19	8.4	8.53
20	8.29	8.8
21	8.6	9.6
22	9.2	9.7
23	7.8	10.2
24	8.26	9.4
25	8.38	10.34
26	8.7	9.87
27	8.84	9.5
28	9.1	9.7
29	8.6	8.78
30	9	9.6
31	8.56	10.06
32	8.69	10.1
33	10.1	9.7
34	7.6	9.5
35	8.12	10.4
36	7.85	10.5
37	8.1	11.6
38	7.4	10.32
39	7.7	9.65
40	8	9.5
Average	8.54625	9.71325

Reflection and Next Steps

The engineering design process proved to be effective. The team was able to work productively, resulting in progress every time work was done. The final craft is capable of moving at a great speed through the obstacle course because of the modifications that benefit its speed. These include minimal weight, slim design, and a heavy-duty tether. It is also very capable in the challenge course; the adaptive hook system allows the craft to take care of all scorable items, and the ROVs small design makes it very maneuverable. The coral recognition algorithm consistently distinguishes between dead and alive coral. One thing that must be prioritized is further experimentation. This will allow the team to make more educated decisions about design choices.

Solutions must be found to solve the remaining problems. For example, some kind of solution could be found to the stiffness of the tether. Otherwise, practice is a very important element in SeaPerch. The team must be sure to regularly practice both the obstacle and mission courses. Along with this, plans should be made to conduct experiments on elements of the craft. Adjustments may be made to the hook system, as well. Depending on how well it does in the future, the up-facing angle may have to be modified to make it pick up floating trash better. In regard to the 3D printed propeller, different "angles of attack" should be considered and tested to analyze how propeller blade design can impact the craft's speed (Sinha, 2019). The variation of propeller blade angles seeks to optimize lift in comparison to drag, to maximize the craft's speed (Jenkins, 2020). Knowing this, different propeller blade designs may return better results.

The development of a camera system on a stock ROV will provide images for an easy to use algorithm provided by Teachable Machine. The stock ROV will be capable of recording footage of coral. The footage is separated into images, placed into the algorithm, and then identified. This will constitute our community outreach project. Given that this system only requires a SeaPerch craft capable of recording video and access to the internet, this also enables exploration of other underwater applications of AI.

Acknowledgments

The ADHUS Kingfishers would like to thank all of its supporters throughout the 2020-2021 competition year. We thank our mentors and teachers, Mr. Nance and Mr. Phipps, for guiding us throughout the construction of our craft. We'd like to acknowledge all of the hardworking staff and volunteers at FAU High and the Cane Institute For Advanced Technologies.

We thank Dr. Phinn and other researchers from the University of Queensland, as well as the CoralWatch Team for contributing fantastic coral image datasets for our recognition algorithm.

Last, but not least, we thank our parents, for letting us stay at school late, driving us to and from practice sessions, and supporting us every step of the way.

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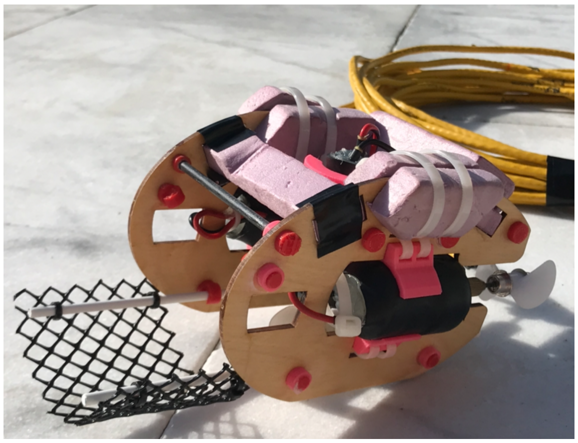
<u>Budget</u>

<u>Item</u>	<u>Price</u>
Carbon Fiber Rods (4)	$6.71
3D Printer Filament	$0.50
Purple Insulation Foam (Flotation)	$5.48
0.25-inch wood frames	$2.00
Motor Collets	$6.50

ADHUS Kingfishers

Boca Raton, Florida, U.S.A.



Middle, Stock, Other Materials

2 Years participating in SeaPerch

1 Times at the International SeaPerch Challenge

Our SeaPerch is unique because: (50 words MAX)

It uses laser cut materials for the frame, uses several different techniques to improve the performance of the motors, and has an adjustable hook system to adapt to its current task. All of the elements are originally designed and created.

SeaPerch Design Overview: (100 words MAX)

The craft's frame consists of two laser-cut frame pieces, connected by 4 carbon fiber rods. The forward motors are built into either frame piece, and the up/down motor is suspended from a motor holder attached to the supporting rods. Flotation consists of several pieces of insulation foam, built into and attached to the sides of the frame. The hook system is adjustable, allowing the craft to score all necessary course elements.

Our biggest takeaway this season is: (50 words MAX)

Practice and experimentation are crucial to the ROV's performance. Experimentation is necessary to make informed design decisions about the craft. Practice is a necessity, because it gets the driver familiar with either course, and more capable of performing it.