Senior Project - Computer Engineering - 2020

The Autonomous Flocking µ-Sub (AFµS) Project

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Introduction

Underwater exploration is a field that holds significant stakes in our future sustainability and has major financial, social, and cibarious implications. Autonomous solutions to underwater data collection are too expensive, unwieldy, or time-consuming to be usable by small research groups, universities, or local governments, even though these entities can greatly benefit from technologies such as this. Our goal is to create a product that addresses these shortcomings by creating a low-cost submarine with flocking capabilities at a size that is easily managed by a single person. Mechanical engineers Alexander Pradhan and Samuel Veith will be designing the hull, thrusters, and renewable power generator for their capstone project.

Design Specs

- Will be able to communicate with subs up to 0.5 meters away
- Will be able to communicate with a BER of < 10%
- Will be able to detect obstacles at greater than 1.5 meters away
- Will be able to hold position within 5 meters of a given point
- Will be deployable by hand
- Will cost less than $500 per sub

Preliminary Results

Movement:

The ATS Mk. 2 will be required to fully realize if our system can meet its design specifications. PID graphs for stationary heading changes performed using the ATS Mk. 1 is shown to the right; the final results show that a desired heading can be converged on in about 4 or 5 seconds.

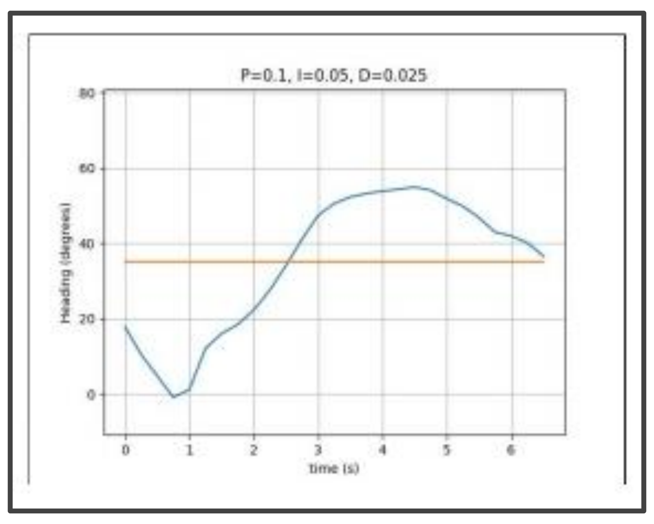

Figure 1: PID graph from ATS Mk. 1 testing

Dead Reckoning:

The goal of dead reckoning is to be able to estimate current location based solely upon sensor information and a previously known location. The method selected for this was using an inertial measurement unit, but it was determined that the error factor in the sensors within our price range were too great for this to be a feasible approach. The lack of precise location data will be factored into the development of the exploration algorithm.

Communication:

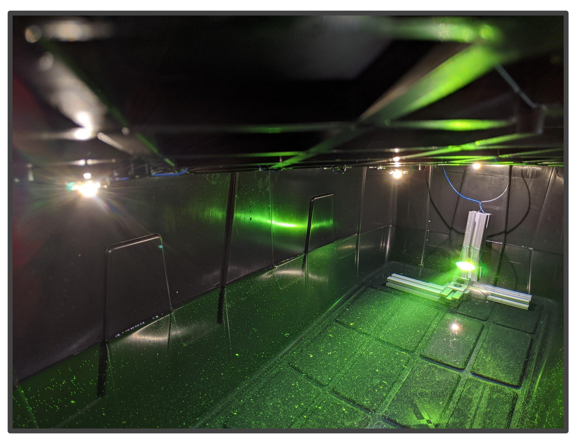
Figure 2. UWOC tank, inside

The communication system was tested using a light-sealed tank with full-spectrum LEDs mounted to the underside of the lid so various ambient light conditions can be created.

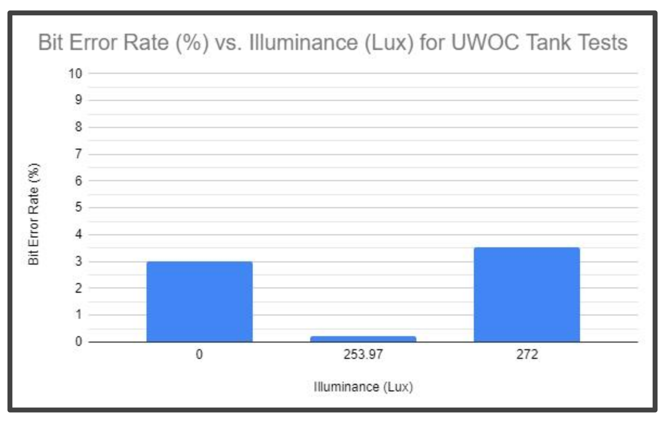

Figure 3: BER vs. Illuminance for tank tests

Through testing, it was found that we are able to communicate at a distance of 1 meter with a Bit Error Rate (BER) of 2.25%.

Sonar:


Figure 4: Successfully read sonar echo. Selected frequency amplitude is shown in blue, and comparator output in purple

For local awareness, a sonar module is being developed to suite our cost and distance requirements. The transmitter is a piezoelectric transducer, and the receiving end is composed of a hydrophone, an amplifier, a 4th order bandpass filter, a AC to pulse filter, and finally a comparator to allow digital reading. Echos from >1.5m have been successfully detected and distance measured. This response can be seen in the captured signal in Fig. 4.

System Overview

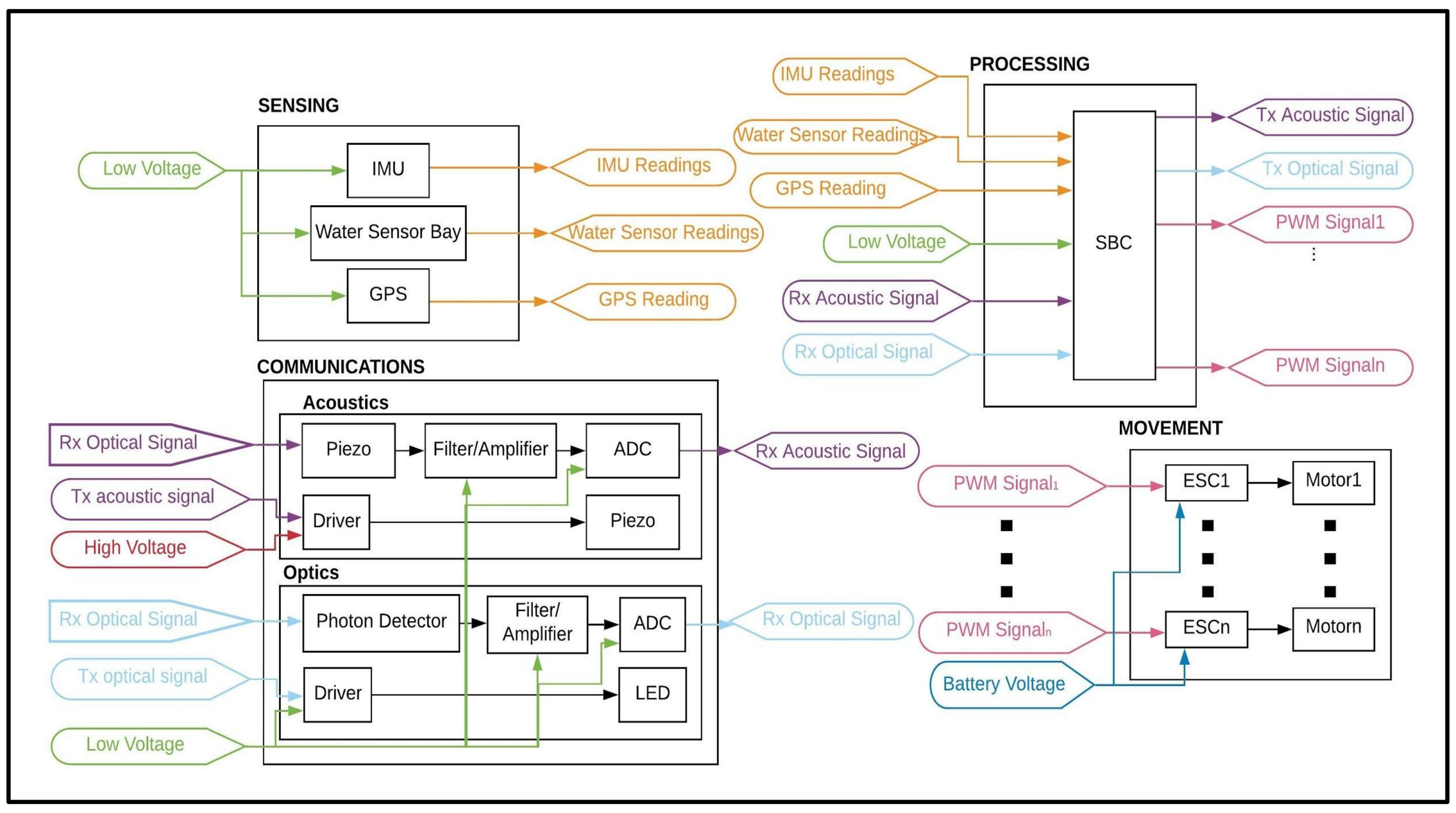

Figure 5: Hardware I/O Block Diagram (omitted: Power block)

Design Strategy

A minimum-viable product approach is taken to ensure both computer/electrical and mechanical engineering teams can iteratively design and test various functionalities as they continue development. Two prototypes are planned, followed by the final sub.

AFµS Test System (ATS) Mk. 1:

The ATS Mk. 1 exhibits free movement in two dimensions, making it ideal for simple motion code testing. This system was constructed during fall term and was used for early control system and dead reckoning tests.

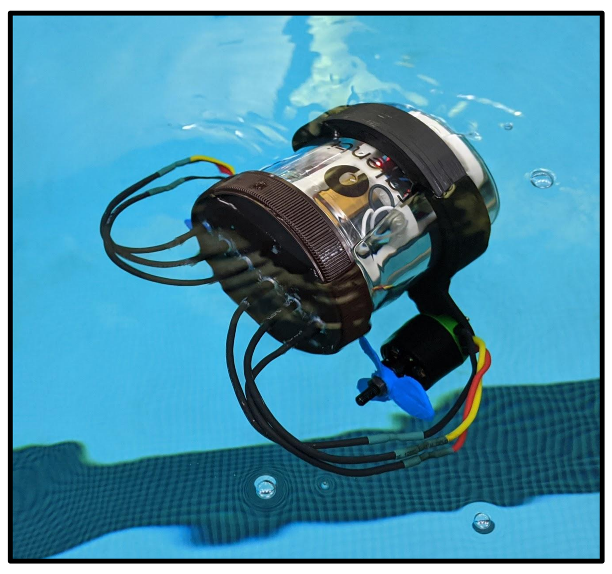
Figure 6: 3D model of ATS Mk. 1

AFµS Test System (ATS) Mk. 2:

The ATS Mk. 2 will exhibit the capability of of three-dimensional movement, obstacle avoidance and communicate optically. This system is currently being manufactured and will be completed by the end of winter term. Testable behaviors include:

- object detection
- data transmission/reception
- 3-dimensional control

The hull will house modular versions of all future electronics to be tested. The external componentry can be hot-swapped to allow for rapid test and implementation as we approach our final design.

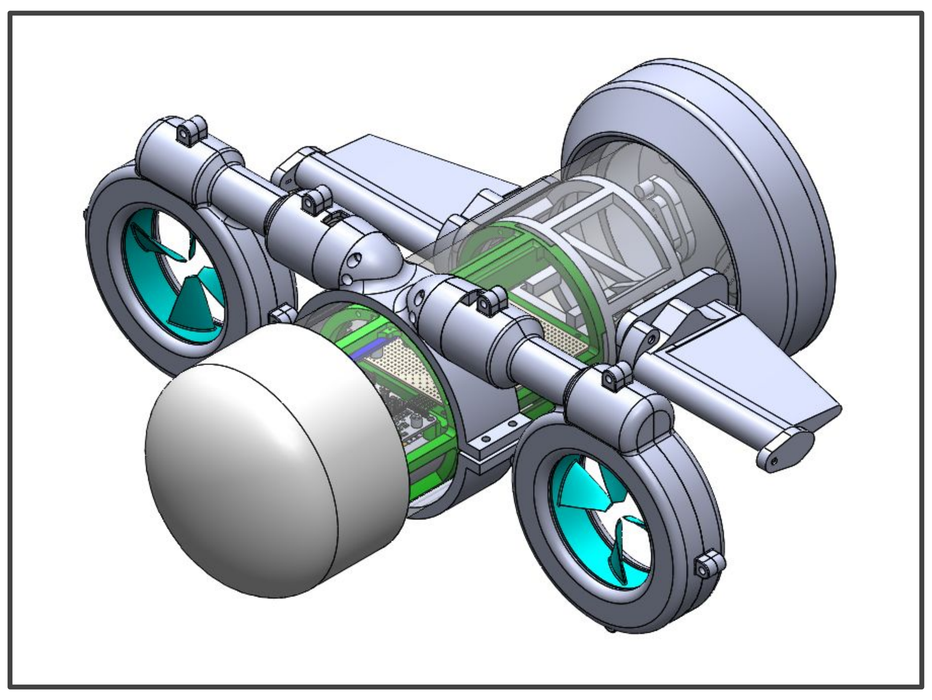
Figure 7: 3D model of ATS Mk. 2

Future Work

All previously stated work will be continued into a 4th term, where improved iterations will be implemented in the MK. 3 alongside features that have yet to be developed. These include capabilities such as active exploration of an unknown environment, the ability to perform residency through passive recharging, and being able to operate within a flock.

Acknowledgements

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