Abstract

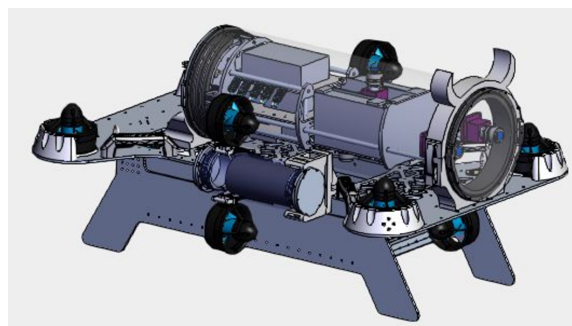
2020 was the first year competing in RoboSub for Underwater Robotics at Arizona State (ASUR). The main purpose of this robot was to accomplish simple tasks with the aim of gaining experience in designing underwater autonomous vehicles (AUV). All the design work on this robot was completed, but due to complications caused by global events, the robot was not constructed or tested. The team hopes to be able to use the lessons that were learned and knowledge gained during the design process to improve their AUV for next year.

Competition Strategy

With this being the team's first year designing a vehicle purpose-built for this competition, an emphasis was placed on being able to complete the simple tasks and start working on the framework that would allow for a more robust system in future years. When the initial design process started, the team lacked access to or knowledge on how to build any advanced sensor packages. Due to these drawbacks, it placed limits on what tasks would be feasible to accomplish. This led to the team's overall strategy for this year's competition being to accomplish tasks that would not require advanced sensor packages or any manipulators. Thus, the focus was to accomplish navigation based tasks. In order to get a higher chance at attempting the mission run in the limited time window, an emphasis on reducing the time the robot spent on navigating between tasks was important. Our focus on accomplishing the navigation based tasks would be helpful for future competitions, since future designs and the working software can be improved and iterated to create more robust systems.

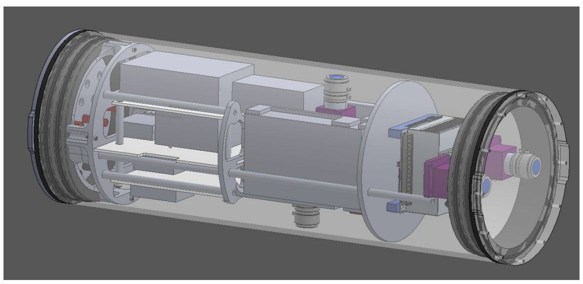
Vehicle Design

The main goal for this year was to design a simple robot that would have the ability to achieve the tasks set out for it without outstripping the capabilities of the team. When designing the robot, parts that were time consuming to custom manufacture were to be bought to decrease the construction time. The decrease in construction time would have given the software team more time to develop the codebase on the actual vehicle. The experience gained from this year would assist the team in designing more complex robots for future years.



Mechanical

The mechanical team had few parts from past years to refer to since this was the first time. Despite this, the team still used complex tools to aid the design of this robot. A focus was placed on ease of assembly and maintenance in order to reduce the amount of time spent troubleshooting mechanical issues. This would have given more time to complete software development and testing. This led to an enclosure which could be easily opened without any need for specific tools, so that field maintenance could be conducted on the electronics regardless of the tools present. This was done by designing an electronics lattice that was attached to the enclosure's fixed end cap, making it easy to pull the enclosure tube off of the robot and conduct maintenance on the electronics. As for manufacturing, custom parts were designed to be 3D printed due to the easy access, low cost and fast iteration time the method provides. Many parts were 3D printed from ABS due to its strength and temperature resistance when compared to the more common PLA. The electronics lattice and the various electronics mounts were 3D printed. Additionally, heavy use of 3D printing allowed for more experimental designs to be tested.

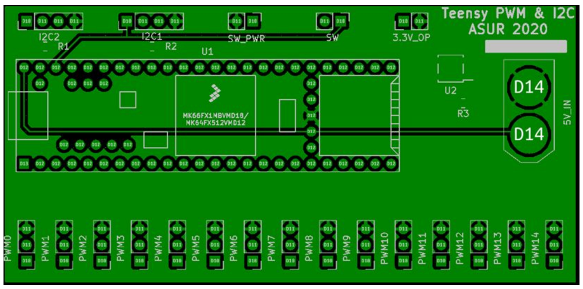


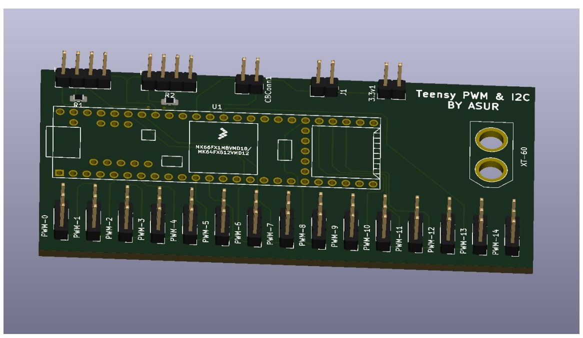
Each year the team strives to develop new and innovative underwater robots. While the focus of this vehicle was on simplicity, there were still some new techniques being tested on this robot. The main forward thrusters and the battery pods are mounted with the combined mount piece. This part was designed using generative design. This process involves an algorithm that designs an optimal part depending on the load requirements, design goals, manufacturing method, and design area constraints. An initial shape is selected and a finite element analysis is run for each load case programmed. The algorithm then adds material in areas of high stress and removes material in areas of low stress. This greatly reduces the overall weight of the part because only material that is necessary for the load cases is left behind. The long term goal of this project was to be able to make larger parts or possibly an entire robot frame using generative design.

Electrical

This year the electrical team had to do a full redesign of the electrical systems of the robot. This is due to no working pre-existing electrical systems from years past. The team decided to approach this design problem by making the simplest system possible in order to reduce cost, complexity and potential sources of error. This resulted in most systems being built with off the shelf components. The team also put an emphasis this year on making sure that the electrical systems were working in sync with the electronics lattice that was designed by the mechanical sub-team. This was done in order to make the assembly process easier. Maintenance was one of key points of the design and with most components being off the shelf, failure in the system could be easily replaced.

One system that did require its own custom system was our thruster control. Due to issues in past years with arduino mega resulting in problems with PWM and synchronization between motors, the team decided to research a new system. This year we planned to use a Teensy 3.5 to control the thrusters. This board gave us better results than the arduino mega while also being cheaper to implement compared to other alternatives. Along with a custom mounting PCB, this system was very space efficient.





Every year, the electrical team tries to develop innovative and dynamic robots with effective electrical systems. Efficiency and effectiveness are the focus of this subsystem of the robot but other methods must be deployed in order to deal with the changing environment due to the pandemic. The system must be able to communicate with other subsystems of the robot and control the program according to various environmental parameters. Each goal and requirement must be given a certain weight, which is then kept in mind while designing and prototyping. The Teensy 3.5 board was chosen with the intention of being effective and efficient within a certain budget while achieving desired results.

Software

Being the first year in which the team has participated in a fully autonomous competition, there were significant challenges in regards to how we planned to achieve the task of navigating and traversing the numerous tasks and challenges within the competition. Initial planning phases took into consideration several motion planning libraries including the MoveIt motion planning framework and the Open Motion Planning Library (OMPL). Early tasks then included running simulation tests to ascertain the optimal library choice while research was performed regarding a linear quadratic regulator (LQR) controller in place of the proportional-integral-derivative (PID) controller which the team has used in past competitions.

While researching motion planning libraries and LQR controller integrations, the team came across the open source auv_gnc library authored by tSender, a past member of the Ohio State University robotics team. This was the final decision as it provided a LQR controller implementation designed to also function with the use of a doppler velocity log (DVL) allowing for the team to achieve more accurate and precise motion. Research and development was then shifted towards familiarizing with the auv_gnc library and implementing with the robot design while preparing to begin simulation testing.

Experimental Results

Due to the ongoing global health crisis during the team's first year, they were unable to meet to physically build and test the vehicle this year. The team was able to conduct initial testing of some of the 3D prints but was unable to run them through all the tests to confirm the validity of the design. The design lessons that were learned for this competition would be used to improve the next vehicle the team works on. The team felt the initial results from the generative design were sufficient and plan on evaluating its use on the next vehicle.

Acknowledgements

Our team would like to thank all of our generous sponsors who have supported us this year, ASU Ira A Fulton Schools of Engineering, Keen Engineering Unleashed, Nortek Group, Solidworks, ASU Undergraduate Student Government, The Arizona NASA Space Grant Consortium, and Sparton Navigation and Exploration