The Inception, Design, and Progress Marker for the USC Turtle: AUV At USC's Newest Flagship Submarine

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AUV at USC is one of the more unique and, in one biased opinion, more valuable design teams at the school. The team is entirely student lead and driven, with contributions being made from Freshman to Senior year students. Every team member contributes to "mission-critical" components of the sub, which was all-the-more necessary this year, as the *entirely* new leadership began its two-year effort to create a new flagship submarine. The USC Turtle is the culmination of one year's effort of a small, close-knit, design team that prides itself in providing a valuable learning environment for its members, while also engineering high quality systems (mechanical, electrical, and software).

I. INTROCUTION

AUV at USC is a student-run robotics team that allows its members to gain real-world experience working on a diverse project while still in an educational, risk-free, environment. The team consistently participates in the Robosub Competition and strives to continually improve through exchange of ideas and involvement in the AUV community. The team uses a full-year design cycle between iterations of the AUV, which was taken to the extreme in this years' cycle. This year AUV at USC has undergone a complete leadership restructuring, and in an effort to start from the ground up, an entirely new robot was created. This involved re-designing the internals and structural components.

II. DESIGN STRATEGY

AUV at USC technically has a faculty advisor, however, the team has opted to receive no help or guidance from him or any other non-student advisor. The benefit of this decision is primarily that all aspects of the team that a faculty member would normally take care of are instead under student control e.g. design decisions, systems integration, and managing financial accounts. Through student involvement in each of these roles, it is expected that team members will achieve a more well-rounded and versatile educational experience.

There are, of course, disadvantages to this approach – namely the difficulty that arises in holding members (leadership included) accountable. On the scale of an automounts design project, there is a fairly quick turnover rate for members and leadership. Issues related to this were exacerbated when the previous team's leadership all graduated and left the team in the hands of relatively new members.

In an effort to get AUV at USC back on track, after several failed efforts to qualify for the competition, the goal for this year was to keep things as simple as possible, and to keep in mind that our ultimate timeframe for a fully functional robot was a two-year effort. The progress we've made this year is promising on this timeframe, we have conceived of and designed a sub from scratch. In doing so, we have also kept all information well documented and easily accessible to both team leaders and general members. This allows for a more streamlined design process.

AUV at USC also competes for resources, specifically time at the machine shop, which bottlenecks productivity. Again, this issue was a key factor in delaying the construction of the sub, mechanically, and with no structure for the sub, electrical and software testing was challenging. We have reached the point, however, where the physical sub is complete, and the more interesting tests can begin. This is not quite as far as we'd like to have made it by this point, but we have achieved a great deal considering the challenges we've faced.

III. VEHICLE DESIGN

A. *Mechanical*

For this, started-from-scratch sub, some aspects of the previous years "Seabee" were brought along. Namely, the modular frame that surrounds the main hull.

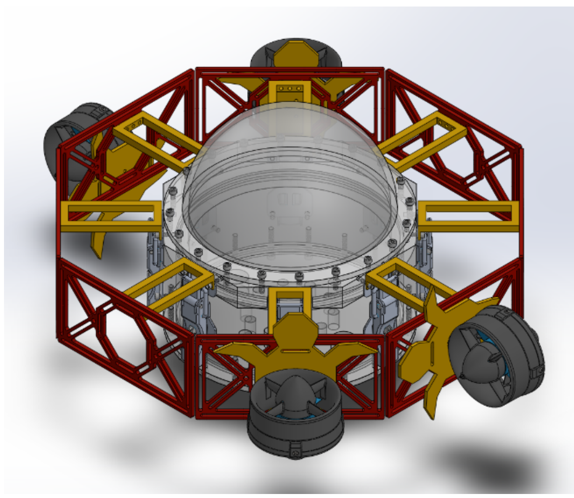

Figure 1: CAD model of the USC Turtle.

The modular frame system allows for components to be swapped out and re-located with ease, which benefits our ability to test and troubleshoot. Additionally, it creates a standard for future additions to the robot, which are well-documented and simple to conform to.

The hull is constructed out of an acrylic tube and dome. The walls of the tube are 0.5'' thick and have an inner radius of 9''. The dome has an inner radius of 8'', and, seals to the tube using a system of latches and a flat gasket – to prevent leaks.

The external frame, and spacers, were machined out of aluminum, in order to meet the demands of repeated fastening of various components. The external frame is highly modular, with many locations to mount any conceivable base or structure. The frame continuous to be an iconic aspect of the AUV at USC's design philosophy, and we figured it's not the time to break from this tradition.

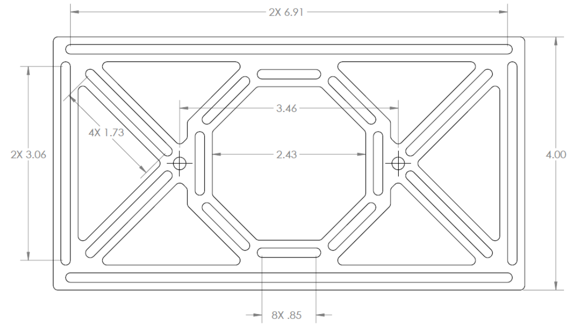

Figure 2: External frame example.

The location of the motors was dictated by an effort to reduce the total number of thrusters. Our previous model had 6 thrusters, while this design needs just 4. This is a by-product of the robots more symmetric approach, featuring a more compact profile and cylindrical layout.

B. *Electrical*

The Turtle electrical system provides the robot and its systems with power and provides the appropriate interface between all of the electrical devices.

Reducing the wiring was a major goal for the USC Turtle, as Seabee was plagued with cable management issues.

As far as computing is concerned, again, a more simplified approach was taken. The USC Turtle's "brain" is made up of a Raspberry Pi and multiple Arduino Uno's.

For eyes, the USC Turtle has two Logitech cameras that are positioned in order to maximize the "field of view" to aid in the robots autonomous analysis.

And for it's heart, the electrical system is powered by two custom +22.2V lithium polymer battery packs in parallel for a total of 20,000 mAh. Each pack contains a Seabee Battery Board based on the ATMEGA 406 microcontroller. In addition to regulating the LiPo cells to ensure even discharge, the Battery Boards actively monitor state of charge (SOC) through use of current integration, or "coulomb counting". Each Battery Board incorporates an LED display to provide visual feedback to the operator.

C. *Software*

Unfortunately, the software side of Seabee was notoriously difficult to wade through, with the bulk of the software team graduating or moving on to other projects, it was near impossible to revive any previous code.

Currently, the software team is focusing its efforts on using ROS, an open-source toolkit developed by Willow Garage, since the 2010 RoboSub competition. ROS, or the "Robot Operating System", provides a language-generic, modular paradigm for the development of software systems.

An effort wa smade to divide the system components into units called "nodes", each of which has at least one dedicated thread and the ability to control parts of its life cycle. When necessary, these nodes are able to communicate via explicitly defined, language-generic messages sent over a named, simplex channel, or "topic". The direction of these topics is determined at compile time; a node can "advertise" an outgoing topic via a "publisher" object or "subscribe" to an incoming topic via a "subscriber" object. However, topics can be redirected or "remapped" at runtime, allowing for the creation of more loosely-defined distributed systems.

There are several main computational problems that arise when creating an autonomous vehicle. The various computational tasks will be subdivided and given there own "brain" in the form of an Arduino or PWB.

The main "pipelines" consist of vision, recognition, and localization. We have maintained code that correctly stabilizes and holds the position of the sub in a swimming pool, which was no small feat. This code is legacy code from previous years efforts, and so understanding and continuing to innovate this code was a main goal for the software team, which they were ultimately successful at.

IV. EXPERIMENTAL RESULTS

One area that the AUV at USC team failed to meet goals was in the area of testing and experimentation. While we did hold multiple "wet tests," they were primarily mechanically oriented, which is to say that they were in effort to determine if the main hull was water-tight. To the extent that this constitutes an experiment, we were successful. The first wet test revealed a major flaw in the construction technique for the dome to tube adapter system. This issue was resolved with a flat gasket system, which prevented additional leaking.

From a software perspective, we were also able to perform a valuable test. Due to the cylindrical hull, there was some uncertainty as to how well our cameras were going to be able to see out the walls of the hull – essentially the amount of distortion due to the concave interior was a source of concern. We were able to place a camera inside the hull and obtain results confirming that there was minimal distortion under water, and that color saturation levels were acceptable for the software recognition system.

Upon the arrival of waterproof connectors, the electrical team will be able to perform many more tests that will make up the bulk of the USC Turtle's development.

V. CONCLUSION

While the AUV at USC team did not quite reach it's goals for this year, we have acquired an immense amount of knowledge that we are confident will carry over to the next year. The current leadership, comprised now of rising seniors, will be lead by a rising Junior into the

2017-2018 academic year, and the primary (non-robot-related) goal for next year is to assure a smooth transition of leadership, which will begin in the Fall alongside a revamped recruitment effort.

We have taken all our setbacks in stride, often with smiles on our faces and laughs being shared. Our team is resilient and optimistic about the future of the USC Turtle, and our drive to excel in the 2018 RoboSub competition will only be increased as we move into the more “fun and exciting” phase of testing the now-realized physical robot we have created this year.

VI. ACKNOWLEDGEMENTS

Support from The University of Southern California, iLab, the USC Dornsife College of Letters, Arts, and Sciences Machine Shop (Specifically Ron and Don, who were an immense help in troubleshooting some of the design problems that arose related to waterproofing), and the Viterbi School of Engineering allowing AUV at USC to continue to be an integral part of student research at the school.

VII. REFERENCES

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