Excalibur

St. Georges School Team Paper
2017 RoboSub Competition

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Abstract— 'Excalibur' is the product of a year's worth of effort by the St. George`s Robotics Team. With the contributions of students from Grades 8-12, left 'Excalibur' left improved in its functionality from its previous incarnation, 'Daedalus'. A number of major changes were made and implemented into the Autonomous Underwater Vehicle (AUV), thanks to its modular design. Multiple hull compartments were reduced to a single, and a new sliding rail system allowing for smoother and easier access to the internal components. Lithium Polymer (LiPo) battery banks were used to increase the amount of useable volume in the hull while retaining the required energy storage ability. I^2C protocols were used to match communications with our rotor hat servo/motor controller attached to the AUV's Raspberry Pi 3b main processor. Our small array of sensors will prevent us from conducting the more advanced RoboSub tasks. Our team's goal this year is to have the AUV focus on basic tasks.

I. INTRODUCTION

The St. George's Robotics team's overarching goal is to create an AUV for the RoboSub competition a product that would approximate industrial construction. Our budget was tightened this year. We had to be more resourceful and innovative with our solutions for building this 'Excalibur'. We did this by choosing cost-effective and easy to maintain parts to provide the backbone of the AUV's critical components. Stepper motors from old printers, waterproof housing from a former underwater camera, and bilge pumps, are in the design of the AUV we are competing with. Overall, the long-term goal of the team is to continue building upon the experiences of previous teams and to refine our AUV into the best that it can be.

II. DESIGN STRATEGY

Our design follows the general structure of a standard dirigible airship (originally expressed in our previous AUVs, Daedalus and Caesar).

Fig 1. Our previous AUV Caesar's dirigible airship design.

The general idea is to have a modular system that permits fast and easy replacement or upgrades of components. Such a system proves to be cost-effective and essential to the functionality and serviceability of our AUV. The compartmentalization of electronics, computer, battery, gimbal and motors allows us to switch any faulty parts out quickly. We have moved from multiple separate compartments to have a singular module with two drawer style decks on rails for the electronics. Previously access to the compartments was unwieldy in practice, sometimes jostling the electronics as they were removed/exchanged.

Instead of spending too much time trying to implement advanced sensors, the team focussed on creating a reliable and robust platform to build upon in the future. We believe we have accomplished this. 'Excalibur' is significantly improved over last year's 'Daedelus'. Our AUV will continue to improve, with its capabilities, strong system, and platform in the years ahead.

The St. George's Robotics Team's goals for the AUVSI competition are well-grounded in reality. The AUV will not be one that completes every challenge in lightning-fast time. Rather, it will be a platform we will keep upgrading its capabilities. It will accomplish more and more challenges as we improve as a team. Regardless of what we accomplish this year at AUVSI, the team is proud of what it has achieved up to this point. Many challenges and setbacks have plagued us throughout the entire process; however, we have managed to pull through and put together an AUV that can perform its tasks adequately. Our strategy in traversing the competition course is simple: to qualify and carry out one or two basic tasks that are within our AUV's capabilities. As such, our team's design choices are mostly updates to previous ones, with only a few new methods being implemented.

III. Vehicle design

Much of the AUV's design choices are inherited from previous years' AUVs. The main hull of the AUV is a watertight, acrylic cylindrical tube, which follows the 'Dirigible Airship' design.

Acrylic is transparent and durable. Quick visual assessments can be made for leaks, stresses, etc. Seal integrity of the sandwiched O-rings and acrylic is a simple visual check.

Two years ago 'Caesar' flooded, an expensive event that killed many electronics boards. Ensuring watertightness of 'Excalibur' was a priority this year. 'Excalibur's' long and cylindrical hull is an inheritance from last year's 'Daedalus'. Only two dynamic access points for waterproofing to the central systems exist: through the main access hatch and through the electrical connectors. This should reduce the chances of another flood.

Modified bilge pump motors act as thrusters, a waterproofed stepper motor assembly and worm gear assembly are placed outside of and beneath the central hull to lower the center of mass for the AUV, simplifying stabilizing the AUV.

The AUV's propulsion system retains the 12V bilge pump motors with their 3D printed casings and Kort nozzles that were used in the past year. Switching to more industrial standard motors was a key talking point between team members but, the AUV still maintains its current motors due to material, software and financial constraints. The bilge pump motors themselves have inherent benefits including: waterproofness, small size and ease of replacement.

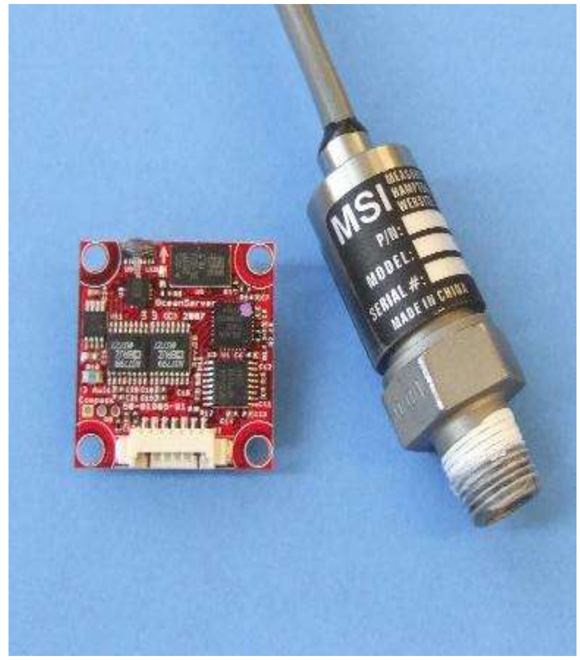

Fig 2. OS-5000USD Compass and MSI Pressure Transducer

Our compass and depth sensor are identical to the ones used last year (Oceanserver OS-5000 USD and MSI Pressure Transducer). These parts for great performance of the sensors and the convenience. The team made improvements to the power feed to the module and code for the compass.

Last year saw the destruction of our Roboard RB-100 (32 bit/x86 CPU @ 1000MHz with 256MB DRAM). Our computer this year has been replaced by a Raspberry Pi Model 3B (64 bit CPU @ 1200 MHz with 1 GB RAM). Although the hardware specifications of the newer Raspberry Pi seem better than those of the RB-100, this switch can be considered a downgrade due to the type of processor and the lack of built-in servo control. An external servo controller was required to reduce stress on the Pi's own CPU. The chosen controller came in the form of a Pi Hat that fits on top of the Pi, occupying the GPIO Pins). This module, the Raspberry Pi Rotor Hat by Geekroo Technologies, was chosen for its ability to drive 16 Servos with full PWM Control, and its low cost. The Geekroo Servo Controller communicated with the Pi easily through common I^2C channels.

A planned upgrade for the AUV's communications last year was the idea for fiber-optic ethernet connection. However, because of testing and time constraints, this idea was deprioritized and has not been implemented. Our AUV is still using the wireless connection existent in Daedalus and Caesar, this year taking form as the onboard Wi-Fi built into the new Raspberry Pi.

Fig 3. Our Raspberry Pi with top-mounted Rotor Hat Servo Controller.

The Software Engineering side of the AUV has been a big challenge, due to the small number of experienced members. With only a handful of members being able to work with the AUV's existing C++ code, the process of updating and creating new code for the AUV proved to be extremely difficult. However, thanks to the simplicity of our mission strategy, a small team of programmers was able to update the code as well as integrate new physical hardware such as the camera and the new servo controller. The code for the AUV is based on the code written for Caesar and Daedalus. C++ was chosen due to its speed, object-oriented nature, and understanding by all of the programmers on the team. Most of the software team come from a Java/C++ background, so the idea of object-oriented programming was common between all the members. This made transitioning from other languages to C++ easier rather than from a language in another programming paradigm. The main challenge for the team was communication between team members. Portions of the software were divided between the members, so the full implementation of the code required members to work together in order to create a coherent program. It was difficult to debug code that another team member had worked on, because of the lack of understanding one team member had about another member's software.

Fig 4. A Rendering of the AUV's Central Compartment.

A major refit was performed on the way components were mounted inside the hull. A couple of systems were tried, including using drawer slides. Ultimately, a tray system inspired by RepRap 3-D printers was selected. Linear bearings were used inside the hull. These bearings and rails would not be derailed by changes in pitch, yaw or roll and provide reliable component access. A lower tray was added with a lead acid battery. This lower tray is which acts as a counterweight to dynamically level the AUV's pitch axis. This was an elegant solution to our leveling problem that was previously manually corrected by added mass whenever internal configurations were altered.

These upgrades, implementations, and goals that our team set have resulted in a platform that is easy to use, robust rather than advanced, and ultimately adaptable and can be built upon in the future.

IV. EXPERIMENTAL RESULTS

As a High School Team, we have had few opportunities for testing as a group, especially during school week days, due to our members being involved in other activities, sports, and teams. Most of our testing has been done on land, with only critical components tested in the school pool. This year our tests have revealed flaws in our AUV's compass, communication systems, and balancing.

At the start of the year, our team hurried to test the compass and depth sensor, a critical component that failed at last year's competition. Over three months were lost due to a team member pulling old components that did not have an A/D converter, a suspected operating system driver incompatibility and the actual culprit voltage drop-off over the USB Bus. Satisfaction was obtained with the first electronics pool test.

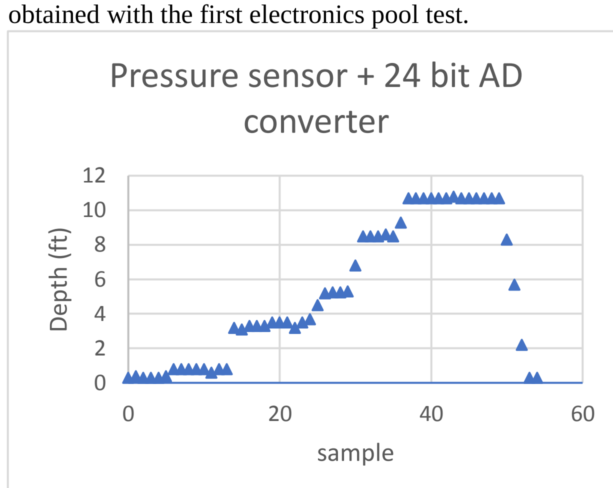

Fig 5. First useful data after debugging electronics.

Our programming team has worked hard to update the classes that controlled each component, such as the new servo controller and the camera. These pieces have been frequently tested for their consistency, accuracy, and speed. Parts such as the PID Controller, the compass code, and the servo controller have all undergone major changes as the hardware was replaced through the year, and have been tested individually in multiple ways before being implemented into one coherent program. This allowed the software developers to progress despite the constant changes in the implemented hardware.

V. Acknowledgements

The utmost appreciation goes our mentor: Mr. Kay, who was steadfast in his supervision over the team's efforts in building and improving the AUV, providing tips and insights which were invaluable in its construction. He attributes much of his hair loss on this activity. We feel fortunate for the opportunity to design and build such a machine, and we are very thankful for the sponsors who helped get to where we are. These very important people are: the St. George's Parents' Association, Whealthfields Lohmann (Hong Kong) Ltd., and Stollco Industries. Through their support, the St. George's Robotics team has been able to build an AUV called, 'Excalibur', that is ready for the 2017 AUVSI RoboSub competition.