St. George's Robotics Team

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Abstract

Creation has always been a gradual, accumulative process; more than a simple birth it's a constant cycle of rebirths. Following our AUV-1 "Albert" in 2009, AUV-2.1 "Bob" in 2013, we are now proud to present St. George's School's 2014 AUV-2.2, "Caesar".

This year's design is a revamp of 2013's. Its general "Serenity" spaceship architecture is maintained - the robot's main components are housed onto the main frame, from which extends outward two wings to which two motors and thrusters are attached. Compared to 2013's design, however, the long cylindrical tube that housed all the components is now replaced by two different containers: a cylindrical main housing that holds all the electronics and a rectangular battery housing.

Onboard sensors include an accelerometer, a gyroscope, a compass, a pressure (depth) sensor, a Hall effect sensor, and a CMU camera. A DreamPlug computer will work with all of these components to control the movement of the robot.

Last year "Bob" served as a mere skeleton of what we hoped to accomplish. With "Caesar" this year we've tried to improve on virtually every aspect. We are, however, yet to polish the AUV as much as we would have liked due to limited time. Therefore we see this competition as primarily a learning experience, a perfect platform for not only evaluating our current design but also communicating with teams from around the world for new inspirations.

1 Introduction

1.1 Team Background

St. George’s School is a private high school in Vancouver, BC. Despite its prestige in its students’ academic, athletic, and artistic pursuits, its robotics program was little known until 2009.

That summer the St. George’s Robotics team competed in the renowned RoboSub Competition in San Diego for the first time in school history, finishing 17th in the competition, and earning the “Best New Team” award. Needless to say it’s an amazing accomplishment for a high school competing against universities.

In 2013 we competed again at San Diego, placing 16th in the written portion of the competition.

The robotics team is divided roughly into three general groups. The mechanical team uses lathes, drill presses, and saws among other tools to craft the pieces required for this complex machine. The programmers work intensely on the sensors and the computer to create an interface that will allow the robot to complete the course effectively and efficiently. A number of members work on communication and marketing: our photographers, videographers, web designers and journalists.

1.2 Robot Design

“Caesar” is our new and improved version of last year’s “Bob”. Though it may sound easy to simply improve upon an existing model, it was in fact no easier or faster than building one from scratch. Our various improvements, re-adjustments and replacements took almost a year - and it’s still not yet completed.

The main electronics are housed inside a cylindrical acrylic tube, inside which the computer, the sensors (along with the batteries that power these electronics) are housed. This tube is placed on top of a red, aluminum main frame. Attached to the bottom of the main frame is the gimbal housing, beneath which is the battery for the motors, housed inside a separate, rectangular acrylic case, held into place by an acrylic frame.

The gimbal is controlled by a stepper motor. It turns a brass rod attached to a worm gear, which is connected to the two thrusters on the wings. Thus the central thruster (which results in the revolution of the worm gear) controls the vertical angle of the wing thrusters. Tilting the wing thrusters upward will cause the robot to rise, while tilting them down will initiate descent. This serves as our depth control.

The DreamPlug computer runs a program which controls the Phidget Servo, which then sends commands to a remote car controller. The controller, needless to say, controls the speed of the motors within the wing thrusters. This serves as our speed control.

1.3 Mission Strategy

To be honest, our goal at RoboSub will be fairly conservative due to the very limited time we had. Every member of our team has been extremely occupied with many other commitments, in and outside school. As a result, although we have finalized our design and various parts, we are yet to polish and test many aspects of its programs. At RoboSub, we aim merely to 1) make the AUV move in a straight line, 2) incorporate the compass and depth sensor, and 3) complete the qualification round.

2 Hardware

The hardware aspect of the AUV can be roughly categorized into two main sections: the mechanical portion, which includes all of the metals, plastics, and other materials used to construct the skeleton of the robot, and the electrical portion, which comprises all of the onboard sensors, computers, and controllers used to navigate the AUV throughout the course.

2.1 Mechanical

The major mechanical parts of the AUV, as previously mentioned, are the main housing, the battery housing, the gimbal, and the wing thrusters.

2.1.1 Main Housing

“Caesar’s body”

(12.5 inches in length with an 7-inch inner diameter and a 8-inch outer diameter)

The central components of the robot are housed inside an Ikelite acrylic cylindrical tube. The team opted for acrylic primarily because the material is transparent, making more apparent any leaks and issues. Acrylic is also quite durable, an important quality considering that the tube houses the most critical electronics of the robot.

The end cap of the tube is crafted from aluminium, selected for its heat conductivity and malleability. These properties reduced the time required to machine the end cap down to size and made it easier to fit the O-rings and waterproof wires into the end cap; furthermore, they allow for effective heat dissipation away from the computer.

2.1.2 Main Frame

"Caesar's bones"

(21.5 inches long, 1.75 inches wide)

Below the cylindrical tube is an aluminium frame which was used to hold the gimbal in place. Again, aluminium was chosen due to its durability and relatively low cost. Because the frame will be immersed in water, the frame was anodized to prevent corrosion and to increase surface hardness. In order to prevent the aluminium frame from scratching the acrylic tube, a piece of StarBoard plastic is used to mount the main housing onto the frame.

2.1.3 Battery Housing

"Caesar's heart".

(exterior 11 inches long, 7.25 inches wide, 4 inches high)

The battery is housed inside a Plano Molding acrylic case . Similar to the main housing, acrylic is our choice here because of its strength and transparency. The case achieves waterproof because of its o-ring seal.

Inside the case dwells a 12V Sealed Lead Acid Rechargeable Battery, along with three speed controllers and a solid state relay.

The battery supplies power to the all of the three motors: the gimbal as well as the wing thrusters.

Each speed controller controls a motor. The solid state relay serves as part of the kill switch. When the kill switch is activated the relay will cut off all three speed controllers, stopping all three motors and thus the robot should an emergency arise.

2.1.4 Thrusters

"Caesar's limbs"

(17 inches long, 2.75 inches diameter)

The thrusters were all crafted by ourselves, as our budget did not allow for commercially available thrusters. Yet again the housing tubes for the thrusters were made of acrylic for it's transparent, lightweight, and durable. The end caps were made of acetal for its machinability.

All three motors were taken from old, unused hand drills and were machined to fit into the acrylic tubes. Each motor is connected to the end cap with a rod. However, as the thrusters will be placed in water and will thus encounter a significant amount of resistance, U-joints were placed on the rods to allow for vibration from outside without damaging the motors.

On the other end of the three thrusters, waterproof wires are connected, bringing power to the motors.

The Gimbal

The central thruster, as previously mentioned, is connected to a worm gear which controls the vertical angles of the two wing thrusters and thus the depth of the robot.

The Wing Thrusters

Propellers were fitted onto the end of the two wing thrusters. These two thrusters enable "Caesar" to move forward.

2.2 Electrical

The electrical components of "Caesar" followed a similar thought process as that of the mechanical components — if a component had to be purchased, the cheapest one that provided the basic necessary utility would be selected.

2.2.1. Computer

"Caesar's brain"

The computer on board the AUV is a DreamPlug system, running Debian Linux with a Marvell Sheeva Core embedded processor at 1.2 GHz, 4 GB of on-board flash memory, and 512 MB of 16-bit DDR2 SDRAM.

This computer was chosen over other viable systems such as a Raspberry Pi due to its low cost and power consumption; even under maximum processing load, the system draws only 5 volts and 3 amps of power.

Despite its limited processing power, the DreamPlug has 2 USB ports, 2 Gigabit Ethernet ports, an SD card slot, and WiFi connectivity, which renders it very effective at delivering all the necessary inputs and outputs. Its small form factor is also crucial, since there is very limited space within the main housing.

The DreamPlug also generates considerably less heat than other more powerful computers, which is crucial when all of our electronics are housed inside the same tube.

2.2.2 Wiring

“Caesar’s blood”

Given that the AUV will be fully submerged in water, it is absolutely imperative that the electronics do not short out because wires come into contact with water.

Although the original idea was to machine waterproof wire connections in house, the team soon discovered that the precision required to create a waterproof seal was not feasible with the equipments available.

We decided to purchase and use Ikelite ICS underwater connectors for the many areas on the AUV that require waterproof seals. While somewhat costly, this was necessary as wiring was arguably the most vulnerable part of Caesar.

2.2.3 Motor Control

“Caesar’s nerves”

The two main modules that affected the control of the motors consisted of the servo controller and Hall effect sensor, both of which granted the robot precise control of the motor positions at all times.

Servo Controller

A Phidget Advanced Servo Controller was used to control

3 Software

Ensuring that the code ran properly was a big challenge, given the very limited testing time the team had. The programming team worked intensely to get the software working as smoothly and as quickly as possible; with only a few members having full knowledge of the API used, this was difficult, but as the team’s mission strategy for the AUV this year was not overly complex, the programmers were able to make do with the little time they had.

3.1 Overview

The code for all of the software for the AUV was written in C++. In this situation, C++ was the language of choice due to its efficiency, object-oriented nature, and relative simplicity to debug and understand. Most of the programmers on the team come from a Java/Python background, so C++ was a somewhat natural transition into an arguably more powerful language.

All of code was compiled for the DreamPlug computer, running Debian Linux on an ARMv5 architecture. Because the DreamPlug lacked the memory and processing power to compile the code natively in an efficient manner, the team decided to cross- compile their code, storing only the binaries on the DreamPlug system. The source code was written using various text editors, and compiled via command line—because of the numerous platforms and systems that the team members used, a standard IDE was decided against.

The main challenge for the team was to find a way to keep everyone in tune with what was meant to be accomplished, as there were numerous aspects of the software that had to be dealt with. For instance, because each of the sensors relied on different APIs, it was sometimes difficult to debug code that one team member had worked on. Regardless, the programming team found the use of flowcharts and other graphical representations of the code very useful.

3.2 Programming Paradigm

The programming team decided to take a class-based, top-down approach to the programming. More specifically, each module that was included on the robot would have its own separate class, thus allowing a fairly simple means of organizing all of the code.

The general structure of the program was first created using a large flowchart. Then, the methods that needed to be implemented were mapped out and placed onto the diagram. After the team agreed upon which classes, methods, and algorithms to used, each member was assigned a different portion of the code, starting from the broadest tasks (e.g. instructing the robot to submerge) down to the most fundamental ones (e.g. measuring and controlling the depth to which the AUV submerges).

3.3 Input Processing

As mentioned earlier, each sensor was given its own class, within the class would include methods to read and process data; since the output of each sensor had to be interpreted in a different manner, the team felt that it made most sense to create a common method among all of the sensor classes to read data.

Most of the sensor input went through the Phidget InterfaceKit 8/8/8 module, which served as a hub for both input and output. This was ideal because the InterfaceKit comprised built-in ports on API methods for reading both analogue and digital input (as the sensors on the AUV outputted both types of data), as well as being able to output information on both the LCD display and in the console log.

Filtering the sensor data was perhaps one of the most challenging problems the programming team had to face. As the data generated by the sensors was very noisy, the team was tasked with finding a means to remove these variations and inaccuracies. A basic Kalman filter was developed to clean up the data; however, due to time constraints, the algorithm more closely resembled a moving average filter.

3.4 Navigation Control

Controlling the position, orientation, and motion of the robot was the next task, after being able to read the data input from the many sensors on the robot. The team decided to have four fundamental methods that would govern the robot's entire mission: followLine(), move(), goDown(), goUp(), and turn(). These five methods represent the highest level of abstraction for the AUV; the team worked down from these five methods to create a functioning robot that could complete the tasks originally set out by the mission strategy.

In programming the motion of the motors, one of the major problems that the team faced was the issue of determining how to control the motors as it changed from one position/ speed to another so that the transitions could be smoother and more gradual. After some research, the team decided to implement a proportional-integral-derivative controller, which would gradually adjusts the speed of the motor as it approaches a desired set point. Despite the fact that implementation of this controller was quite complicated, the team found great success in navigating the AUV smoothly after this was completed.

Possibly the most important function of the robot, the followLine() function, was the most recent to be implemented. The followLine() function utilizes the Camera, also a more recent addition. There are several steps to the process. First, the camera takes a picture. This is transferred via serial bus to the computer. Once in the computer, the image is processed by finding the centroid (center of mass) of the line colour at regularly spaced rows. These centroids function as the position of a line at any given height. The differences between adjacent centroids is then averaged, and returned as the error. Finally, this error number is passed to the PID controller, which returns the correction for the motors.

4 Conclusion

It is clear that the St. George's Robotics Team is not a bringing an AUV into the competition this year that will amaze the audience by completing every challenge in lightning-fast time — far from it, in fact. The team is, nonetheless, quite proud of our efforts in the past year. Challenges and setbacks plagued us throughout the entire process. But we fought on.

We hope to learn as much as we can at the 2014 RoboSub Competition. A number of improvements have already been planned for the robot in ensuing years; our experience at the competition this year will only further inspire us.

In the end this AUV serves no practical purposes. In a few years there will without a doubt be better AUVs built with greater ease, less cost and better quality. Each and every one of us knows this, but each and every one of us persists on this task nonetheless - not out of commitment, but out of love. As the torrent of time rushes on relentlessly, the world will forget about this AUV we've built - in fact the world might have never even taken notice of it.

But we will never forget. We will never forget the hours we've spent with the machines the parts the electronics. We will never forget the time we've spent with our friends our mentors. We will never forget our will to challenge ourselves, our courage to face the challenges, our ability to defeat them. We will remember the sweet successes and the sweeter failures, the tiresome days of work and the even more tiresome days of rest. Building the AUV is not a mean to an end; it's the mean and the end.

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