Prairie View A&M University Autonomous Underwater Vehicle (PVAUV): Development and Design of the Nessie AUV

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ABSTRACT--Team PVAUV consists of undergraduate engineering students from Prairie View A&M University in Prairie View, Texas. By designing an AUV, the team members will have insight and experience in designing and fabricating, to a smaller scale, what oil and deep sea exploration companies are currently working with. The goal of the project is to expose the students to a more in-depth design process and manufacturing to allow them to get an understanding of what could be expected of them in that type of work environment. To create a fully functioning AUV, the AUV team followed the design process: problem definition, literature review, concept generation, analysis, manufacture, test, and refine design. Major system design includes electrical infrastructure, mechanical design, and software architecture. The AUV will be used for the 18th annual AUVSI RoboSub competition.

I. INTRODUCTION

The PVAUV team has been doing research on AUV technology for only a few years and is always looking for new ways to improve. The AUV has also changed in design to suit its needs and objectives. With the support of our advisors and sponsors, we designed and built the AUV by using the skills we have gained with engineering. Lots of hands-on experience, trial and error, and problem solving were used in order to get this project to its current state. After several months in the design stage, goals were established. This year, the team plans to surpass the previous goals.

The Autonomous Unmanned Vehicle Systems International (AUVSI) Foundation, Office of Naval Research (ONR) and its sponsors will be having the 18th Annual International RoboSub Competition this July 2015 in San Diego, California at the Space and Naval Warfare Systems Command's (SPAWAR) Transducer Evaluation Center (TRANSDEC). AUVSI foundation and its sponsors recognize the need for finding and learning new ways to develop and use unmanned systems. The need for finding young engineers to input their knowledge is what the AUVSI foundation wants to accomplish with the associated competition. AUVSI gives everyone an opportunity for motivation with challenges and teamwork to accomplish a unique and rewarding goal.

II. PROJECT GOALS

The goal is to design a stable system AUV with integrated visual technologies with the capabilities of achieving underwater tasks. The objectives for this project are:

- Achieve and stable and lightweight design
- Improve hydrodynamics on the AUV compared to 2013-2014 design
- Reuse parts from 2013-2014 design such as frame and thrusters
- Improve waterproofing and stability
- Achieve at least two or more tasks at the competition

III. PROJECT PLANNING

The team stayed on task by using Microsoft Project. This program helped us stay on time with our deliverables and objectives. Timelines and Gantt Charts were used to keep track and check off things as they got done. Figure 1 shows a small sample of a timeline that was used for keeping tabs on the project.

Task Number	Task Description	Objective(s)	Deliverables	Duration	Start
13.1	Research prices and distributors for necessary materials.	Generate a list of the best three prices and source of ordering acrylic weld, aluminum plates, O-rings, waterproof connectors, batteries, and charger.	Bill of materials for acrylic weld, aluminum plates, O-rings, waterproof connectors, batteries, and chargers.	1 day	Mon 2/2/15
13.2	Place order for major materials needed.	Order the approved acrylic weld, aluminum plates, O-rings, waterproof connectors, batteries, and chargers from the bill of materials.	Acrylic weld, aluminum for simpson ties, O-rings, waterproof connectors, batteries, and charger.	1 day	Mon 2/2/15
14	Design battery tray.	Design a bettery tray that supports the decided upon battery configuration, and that fits in the acrylic hull of the AUV in a stable and balanced manner.	Battery tray.	4 days	Mon 2/2/15
15	C.A.D.			5 days	Mon 2/2/15

Figure 1 Timeline Sample

The concept design process took longer than expected, but helped us in the long run because we had something to base our final design on. Each part of the project was broken down and evaluated separately. Concepts were drawn up for each individual section and ranked. The higher ranked drawings were then combined and a first concept drawing was done shown in Figure 2.

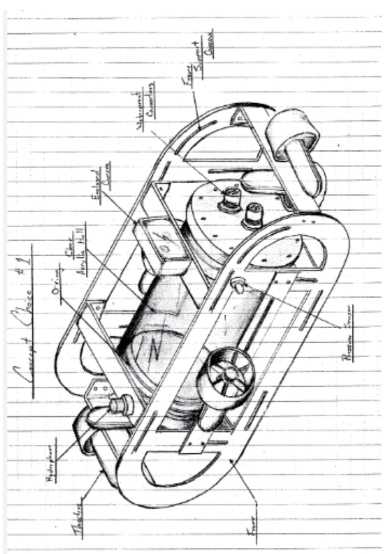

Figure 2 First Concept Design

IV. MECHANICAL SYSTEMS

Nessie's structure system consists of a clear acrylic hull, aluminum caps, aluminum side and cross frames. Our main goal was to improve last year's waterproofing. We achieved that by adding O-Rings to the caps. The entire assembly was then drawn up in NX 7.5 CAD software and analyzed with Abaqus CAE 6.12 and Hypermesh 13 software for structural rigidity. The AUV also was analyzed for flow simulation with Solidworks Computational Fluid Dynamics.

A. Hull

The hull of the AUV was sized to fit and protect all the internal electrical components. The main hull is designed with cylindrical acrylic tube that has aluminum caps. These caps provide the waterproof ability with the help of O-Rings that are sized and fitted to Parker's O-Ring handbook. Figure 3 shows the caps with their O-Rings being installed and also installed to the acrylic hull tube.

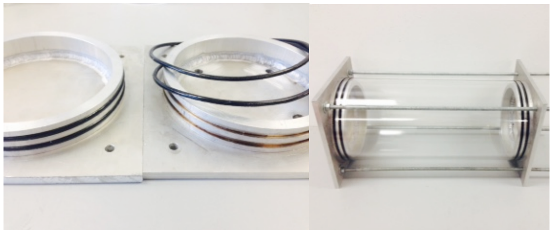

Figure 3 Hull Assembly

B. Frame

The structure for the AUV needs to be sturdy, light weight, and smaller than or equal to the maximum size constraint of 6’ x 3’ x 3’. Part of the constraints for this year includes reusing as many components from the previous year’s AUV as possible; therefore, the structure of last year’s AUV will be used. The structure is made of 3/16” aluminum 6061 and it is 2’ x 1’ x 1’ in size. The shape of the structure is also compatible with the concept cylindrical hull that is roughly 18” long with an outer diameter of 8.5”. The structure selected will satisfy the size requirements and will be compatible with the concept hull design, further detailed analysis will be performed to ensure that the thickness of the aluminum will endure the forces the structure will have to endure. Figure 4 shows the structure design.

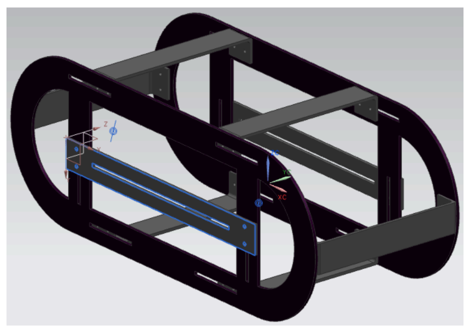

Figure 4 Frame Structure

C. Camera housing

This year the team decided to have Nessie try some new obstacles. In order to achieve that, a unique camera housing had to be designed and manufactured. The housing consisted of welded aluminum and two acrylic plates. Figure 5 shows the enclosure model.

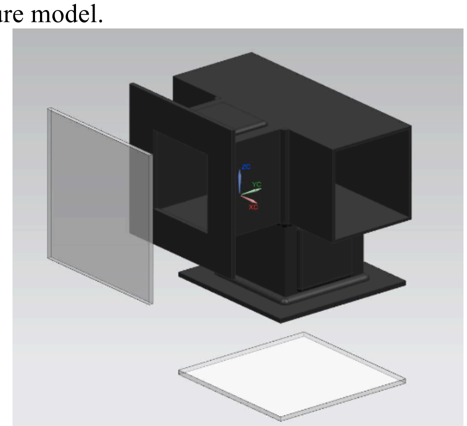

Figure 5 Camera Enclosure

D. Analysis

Nessie was analysis in two separate ways; Structural, and Computational Fluid Dynamics (CFD). Since Nessie was symmetrical the Finite Element Analysis (FEA) was done with only half of the structure to save time. This half of the FEA had over 91,100 hexahedral elements and used advanced software like Abaqus CAE 6.12 and

Hypermesh 13 for solving. The structural and load bearing components were all verified. Figure 6 shows the structure of the AUV all meshed and ready for its analysis.

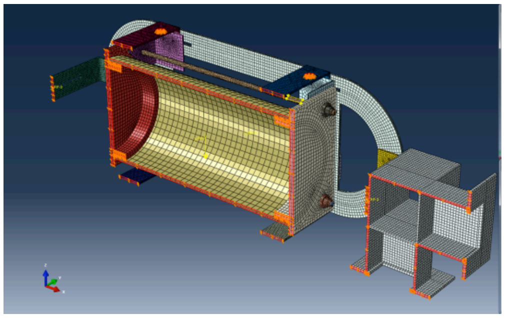

Figure 6 Meshed Structure

Nessie was tested for its resistance to its surrounding environment. With the aid of Solidworks Flow Simulation, the program computed a drag force of 0.171 lbf while moving at a blistering speed of 6 inches per second. This data was used to calculate the capabilities of the speed of the AUV. Figure 7 shows the structure under CFD load and shows how it reacts to its surrounding fluid.

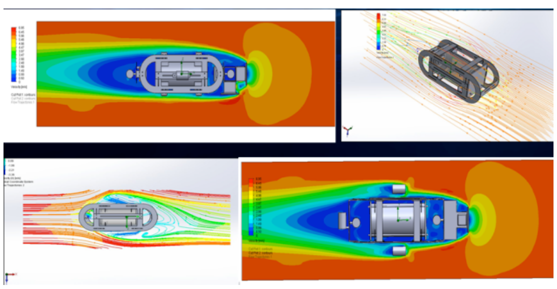

Figure 7 CFD Results

E. Buoyancy and stability

To keep the AUV from rolling and swaying underwater, the center of mass was calculated and used for finding the center of buoyancy. From these calculations the differences between the positions of mass center of gravity acting on the body were determined and the locations were noted. From the center of buoyancy location, PVC tubes were added. The sizes and lengths of the pipes were based on the data obtained from buoyancy calculations. Figure 8 shows the added PVC tubes.

Figure 8 PVC Tubes for stability

F. Thrusters

For propulsion, Nessie has 6 Seabotix BTD150 thrusters. This is one of the main components that was reused from last year's AUV. These thrusters have been reliable in the past and have endured all the testing that the AUV has done. This thrusters at half power provide the AUV with a speed of 6 inches per second. This is the speed that was used for the CFD as explained above.

G. Connectors

Connectors are a very important component to the AUV's communication system; Connectors from SubConn were used due to the reliability and connect-ability. These SubConn connectors are Wet-Connect which mean that they can be connected or disconnected underwater. The connectors were installed directly to one of the end caps. Figure 9 shows the connectors being installed to the cap.

Figure 9 SubConn Connectors

Mechanical Overview Statistics

- Weight: Dry 60 lbs
  Submerged 5 lbs
- Speed: 6 inches per second
- Size: 40” L x 17” W x 14” H
- O-Ring waterproofed caps
- 6 Seabotix BTD150 Thrusters
- SubConn Wet-Connect Connectors

V. ELECTRICAL SYSTEMS

Nessie's Electrical System includes both power and controls. The controls system saves processing time by interfacing a data acquisition and processing module and a desktop computer in a server/client configuration. Splitting the processing work allows for heavy lifting and quick response times to make the best of the 30 minute time limit of runs. The power system consists of easy to find, modular, and replaceable components, leaving room for upgrades and effective repair.

A. Power System

The system must run completely off of DC power supplied by high density batteries. Immediately arrays of 18650 lithium ion batteries were considered against 6 cell lithium polymer batteries. Ultimately, it was decided that the discharging characteristics of lithium ion batteries was preferable, as there were no plans for the implementation of a battery management unit within the submarine. From there, a power budget sheet was created using the specifications supplied with chosen components in a worst-case scenario. Using this data, the number of batteries, as well as the necessary guage of wire was determined. The Lithium Ion batteries are protected from cross charging by using diodes with high specifications appropriate for the voltage and amperage needs of the vehicle.

Power is distributed to a rail in which every device in connected in parallel. Voltage regulators step down voltages where needed in order to supply power to lower voltage devices.

The power system supplies power to the computer system, the motor controllers, and the data acquisition system. The killswitch is wired in series with a relay which uses a small impulse from a much smaller amperage rated ip68 switch in order to turn off power to the thrusters.

B. Computer System

The computer system is a mini-itx motherboard using an m2 solid state drive, a single DDR3 8GB RAM module, and the Intel I-7 4790S low power processor with onboard graphics. It is powered using the M4-ATX power supply by Minibox. The computer system interfaces using USB connectors with the motor controllers, the NI MyRio, and the Logitech C920 webcams.

The computer's functions are to provide input to motor controllers, and take information from the data acquisition system while processing video feed all using NI Labview.

Windows 7 OS was used as a way to interface devices conveniently in terms of drivers. An improvement to the OS would include using a linux based distribution and making the most of system resources. This would also be convenient, because NI Labview programming transfers seamlessly to a Linux system. Electrical engineers are recommending Debian for its stability.

C. Data Acquisition System

Data acquisition simply means taking the input from various sensors and preprocessing that input for use by the computer. The sensors include a Sparkfun 9DOF razor IMU, three Aquarian Audio H1c hydrophones, and a Honeywell MLH050PGP06A depth sensor. Each of these interfaces serially with NI MyRio which then handles pre-processing of the data by applying sensor fusion and an extended Kalman filter.

All of these devices are powered from interfacing with the NI MyRio, which itself is powered through a voltage regulator connected to the power rail.

The filtered values are then sent to the computer system which will use the values to create outputs to the control system.

D. Controls System

6 Pololu SMC 24v12 are interfaced using USB with the computer. These motor controllers take in voltage from the parallel power rail and throttle voltage to the Seabotix BTD150 thrusters. The amount throttled is determined by values sent serially over the USB connection.

These controls are determined by which task the AI has selected based on inputs from the environment.

Nessie uses only IMU and depth sensor data in order to complete the gate task. It does this by recording the original orientation and stopping forward thrust to make adjustments to orientation.

Once the gate task is completed, Nessie switches to visual data and its relative position to the center of the respective camera to control itself. The completion of line following tasks creates a counter which is used to determine the current task.

E. Networking System

Preliminary research of the networking system showed that a USB device could be powered with up to 15 feet of cable. In practice, only low voltage devices such as computer mice will work. The voltage drop over such a length of cable proved too much distance for the powering of a USB wi-fi card. As such, a separately contained system for networking was implemented by using a waterproofed box which will float on the surface. The system uses a powered USB hub and a voltage regulator with nickle rechargeable batteries as the power source. Since this power source was narrowed down to causing interference, it was grounded on the negative terminal of the batteries to the endcap.

The wi-fi card connects to any wireless router which allows a programmer to connect to the computer via LAN. Windows remote desktop software is used to inspect code as it updates in real time and allows for quick readjustment. This system is not required to run the robot, it is only for testing purposes.

VI. TESTING

Nessie has been in testing since early May, 2015. Beginning stages of testing showed things that could not have been done out of water. While in the water, the AUV showed new stability and balancing issues that were quickly resolved by moving things around on the frame. Due to a cross charging issue from the batteries, run time was much less than expected. Running the Submarine without a constant eye on the automated inputs made by the computer also created issues with readjusting programming. Using high voltage diodes in series with the positive terminal of the batteries increased run time drastically from 20 min to nearly 2 hours. More of this time was also efficient by creating a wi-fi enabled connection box that floated on the surface of the water. That puts Nessie well inside the allotted time limit of 30 minutes.

VII. CONCLUSION

VIII. ACKNOWLEDGMENTS

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