S.O.N.I.A AUV Technical Design Report

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***Abstract*— S.O.N.I.A. is a Canadian student club from *École de Technologie Supérieure* that involves 20 members who dedicate countless hours to engineer an autonomous underwater vehicle (AUV). There are four departments: administration, electrical, mechanical and software, each of which contribute to the achievement of the project. It is essential for an AUV to be able to interact autonomously with its marine environment using its incorporated resources. With its improved control and deep detecting algorithms and new computer Jetson AGX Xavier, the submarine can calculate its speed and distance more efficiently and detect objects in shorter time-intervals. The team's current focus is improving the control algorithms for the submarine to travel at a faster speed. In addition, with the NVIDIA Jetson AGX Xavier acquired this year, the submarine deep learning algorithms process faster and the submarine consumes less power. Additionally, the members optimized the I/O control board to incorporate a robotic arm. The dropper and torpedo solenoid technology was improved to be more efficient and less power consuming by using only one solenoid. The team purchases the Tritech Gemini 720im multibeam sonar. At first, it may only be used to gather data, but the team is trying to make it ready for action. With its new features and processing systems, the AUV will once again accomplish Robosub 2019's challenges.**

Keywords—autonomous, underwater, submarine, vehicle, robot, Deep Learning, sonar, NVIDIA

I. Introduction

S.O.N.I.A. is an autonomous underwater vehicle scientific club that was established at the *École de Technologie Supérieure* in Montreal. Its first design goes back to 1999. The robotic team has its name given under the acronym *Système d'Opération Nautique Intelligent et Autonome*. Thus far, the team has dedicated their efforts to engineer eight prototypes. Their objective is to improve their design and strategies for every year's competition. This year is special for S.O.N.I.A since it is its 20th anniversary and participation to the Robosub competition held in San Diego, California.

Although each member focuses on different aspect of the project, such as mechanical, electrical and software, all contribute to the continuous improvement of the submarine. The team believes that sharing knowledge is essential for the advancement of robotics. This year, S.O.N.I.A wanted to give back to the community by presenting its project in elementary schools. The team firmly believes that the presenting a project as ours can inspire children to pursue their studies in a scientific field. This project will stay throughout the years since it received positive feedbacks. In fact, this year only, the presentations reached more than 2500 children.

The submarine is a continuation of the previous years' prototype. Since 80% of the team consist of new members and with old members finishing their bachelor's degree next year, it was important to allocate time to explain every part of AUV7. One of the main objectives was to increase the navigation speed of AUV7. Since it was one of the main issues to complete the tasks during Robosub 2018, the software team has developed new control algorithms. In addition, a single Jetson AGX Xavier replaced the old embedded computer and Jetson TX2. In parallel, the electrical team focused on integrating this new device, and took the time to design new backplanes, PSU and I/O boards. The mechanical team faced great challenges integrating the new computer and adding new components such as the robotic arm and the multibeam sonar.

Competition Strategy

A. *Mechanical*

For Robosub 2019, the mechanical team had to add new external modules. The latest droppers module was redesigned to achieve a better velocity than the golf balls used in 2018. A robotic arm was also acquired to be able to complete more tasks. Since it is AUV7's third year of competition, the team members are now accustomed to the submarine. The mechanical team competition's goal for this year was to be able to have a reliable platform that is ready to overcome every obstacle.

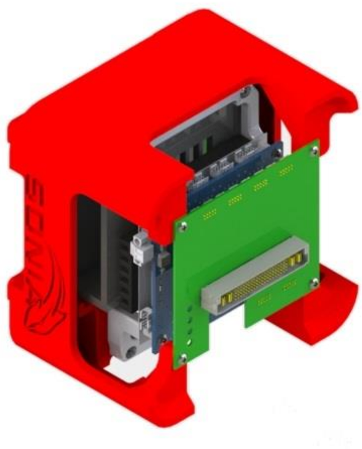

Figure 1: Xavier Integration

B. Electrical

The electrical team made a substantial amount of conceptual work for the upcoming season. The new power supply have a feature to monitor the submarine's consumption. Since many new add-ons were implanted, it was crucial to make sure that AUV7's consumption was not damaging the batteries and other components. In addition, to integrate the new Jetson Xavier, new backplanes were needed, and a new electrical power distribution was made (Figure 2). Last, a new I/O board was needed to integrate the new robotic arm and multibeam sonar.

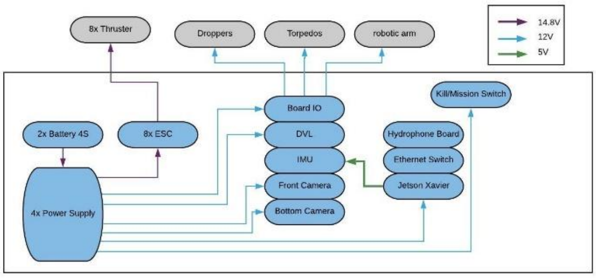

Figure 2: Electrical Power Distribution

C. Software

This year's main challenge for the software team was the arrival of numerous new members. The main competition team is composed of one senior member and three new members. Similarly, to last year, the team focused on two different techniques for image recognition. All the tasks involve deep learning except for one. In fact, detecting the Jangshi involves the vision filtration module using OpenCV.

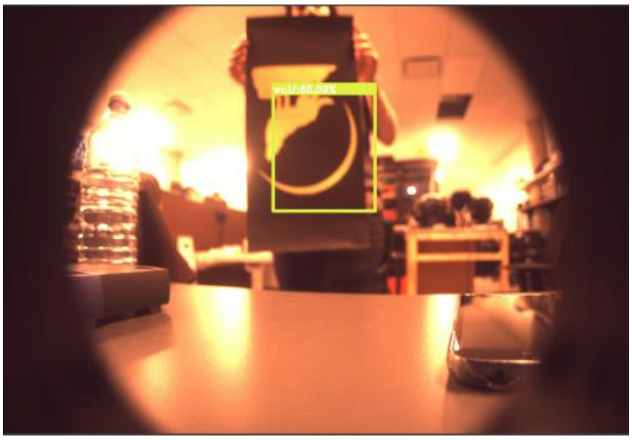

Figure 3: Deep Learning & Vision Object Detection

II. DESIGN CREATIVITY

A. Mechanical

This year's main emphasis was devoted to the optimization of the platform to perform at high standards. One of the priorities was the revision of the angle brackets that support the motors, at the four corners of the submarine. Now, the thrusters are mounted in the strongest way possible to the submarine, and lifting the submarine is easier and safer than ever. The revision also allowed the addition of strong legs to rest the submarine and improve cable management around the brackets.

Later this year, the team had to face an obstacle to operate the submarine: the onboard computer was damaged and would not work. The mechanical team had to make a quick move since sourcing a similar model would take months as they were trying to see if we could make a transition to the new Nvidia Jetson AGX Xavier. After testing on the Jetson TX2, the team pulled the trigger and integrated the new Xavier. Integrating this new computer was a big challenge because its encumbrance is much higher, making it impossible to use in the current mechanical platform setup. To overcome this, the mechanical team flipped the orientation of the submarine front and back, effectively switching the front camera to the back with the hydrophone acquisition module and the bottom camera port, and switching the Xavier rack to the front, where there are fewer constraints. The Xavier rack also houses the kill-switch and mission sensors as well as the Ethernet switch, making it a designer's nightmare. A side effect of this switch is that the hydrophones are picking less noise coming from the computer.

Like most years, to prepare for the new tasks, the mechanical team worked on improving our torpedoes and droppers systems. Last year's ones worked well, but a more finished prototype was required. The torpedoes were made smaller and less buoyant, to make them more precise, with the drawback of them not coming back to the surface by themselves. The launching module itself is now machined out of aluminum instead of 3d printed and is more compact. As for the droppers system, the markers were changed from golf balls to smaller markers, which are urethane cast with a chrome ball bearing inside. The droppers systems is quite similar, dropping both markers at the same time.

Finally, for 2019, the mechanical team found out that a lot of time and effort were required to develop the submarine's abilities in the manipulation tasks. Since the mechanical team did not have the time to develop a new grabbing system, they decided to acquire the Blue Robotics' Newton Gripper. They believed that it was easy to use and would suit well for grabbing PVC pipes. Lastly, they designed a way of mounting it to the submarine.

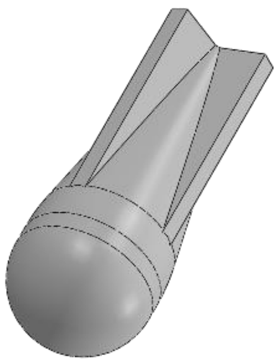

Figure 4: Droppers Marker

B. Electrical

The electrical team had to face many design challenges this year. The focus was to design new Power supply to be able to monitor the current usage and the current spikes in the active submarine. Since each battery is connected to a power supply card with three channels. Two of the channels have the same nominal voltage as the battery (16.0V), allowing a direct connection to the four ESC. To supply the other components, the third channel has a switch-mode power supply (buck converter) that reduces the initial 16.0V to 12.0V. The voltage conversion is a mandatory process as the channel supply power to important submarine components. One of the problems that the electrical team encountered when adding a new module in the submarine like the robotic arm or the Jetson AGX Xavier was that they did not know how the charges were distributed in the submarine. The previous power supply PCB provided a current measure, but the measurement was noisy. This new power supply was designed to obtain a more accurate current measurement. It uses Hall Effect sensors (ACS722).

In addition, in order to improve the submarine's accuracy, S.O.N.I.A. decided to purchase a new sonar. The previous sonar owned by the team was composed of only one beam performing a scan, which created some uncertainty in object identification. The electrical team worked on adding this module to the submarines using a Seacon connector.

With the new configuration of the on-board computer, the Jetson AGX Xavier presents different USB configurations. Therefore, the team had to design the new backplane's PCB between the computer and the rest of the submarine. In addition, it was needed to remove some USB connectors from the current backplane to add Ethernet connectors. The team had to think about all the new modules to integrate in the future year to be certain that enough Ethernet connectors were on the backplane. Lastly, a USB hub was added to easily connect the USB to the Jetson AGX Xavier.

Robosub's rules of this year involves catching a vampire in a bin. To do so, the electrical team had to integrate the new robotic arm bought by the mechanical team. This new module was added to the I/O board since it only needed a PWM signal. The I/O software was changed as well to be able to control the robotic arm.

C. Software

Last year, the software team worked on integrating deep learning for object detection. Python was used for the detection algorithms implementation. The vision recognition system using OpenCV was not used since the deep detection was fully functional for all the tasks. Also, the team has decided to use the Vision OpenCV again for many tasks since it is a robust implemented feature in the submarine software.

A new sonar was acquired to replace the old one that has not been working for 2 years. This sonar is the Tritech Gemini 720im. Since the sonar is a multibeam type, it allows scanning a multiple times per second the objects present in its vision field. The integration of the sonar was one of the main projects, gathering the three departments of the student club. Its acquisition was motivated by the belief that it will prove to be an advantage in long-range detection and alignment. Indeed, the sonar is not affected by changing meteorological conditions, which plague conventional vision systems.

Having last year's knowledge, the software team was able to improve the methodology for object detection. A new platform allows the automation of model generation. The software team set up an Airflow pipeline to perform the different model generation used in deep learning in an automatic manner. This pipeline consists of three stages. First, it needs to transform the video feeds in a 'rosbag' into an image. Then, it needs to upload the images to the google cloud platform server. Last, it needs to extract the data from Labelbox to convert the images into 'tfrecord' that are ready to be dragged.

In order to be certain to have a powerful image detection tool, SONIA changed its internal computing system and Jetson TX2. The team bought an Jetson AGX Xavier. Because of this change, the software team had to adapt the code for it to be compatible with the ARM architecture. The ARM architecture is much more adaptable for embedded systems. In addition, the Jetson AGX Xavier's internal GPU is more powerful than the previous TX2 Jetson's internal GPU. This powerful addition allows deep learning to be faster and pushed further than before.

Last year, one of the biggest issues for AUV7 was that it was not fast enough. Therefore, this year, the software team implemented a new control method in addition of the position control. In addition, a new speed control method was developed to help the submarine move faster. Instead of setting a location to go, a speed value and orientation is set until the next event. This new method allows AUV7 to move faster when travelling from obstacle to obstacle.

Like last year, the software team uses their mission system operated by a state machine. It allows the submarine to accomplish complex tasks based on many simple tasks.

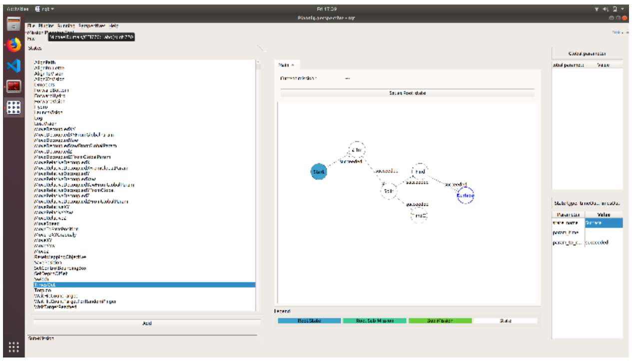

Figure 5: State Machine Mission System

The team uses a simulation program to monitor the mission states, and to test offline missions.

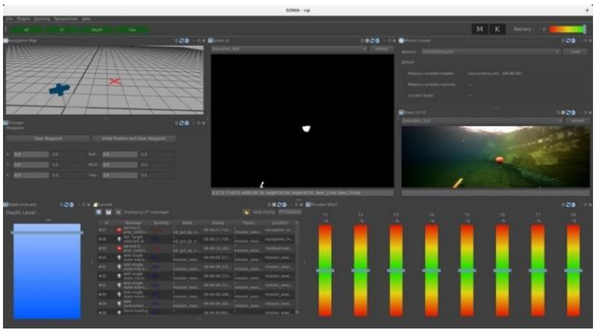

Figure 6: Simulation Platform

III. Experimental Results

At ÉTS, students have three regular semesters a year. Therefore, when participating in a scientific club like S.O.N.I.A., the need to go to school persists even during summer right before the competition. Many students are taking full course load, and some are working, while others are involved in extracurricular activities. In order to have a well-organized planning, a schedule is sketched at the beginning of each university's semester. The planning evolves throughout the year, as priorities move forward and back. During the fall semester, weekly meetings start. Milestones are given for the whole semester. Testing timeframes started slowly to let the team members think about new design projects that they could achieve for the upcoming year. During the winter semester, the team had to test the new configuration of the submarine. The software team made more updates that needed to be tested. The tests took place in an indoor pool due to the weather conditions. During the summer semester, the number of tests and meetings increased to two to three times a week as the competing date approached. It is understood that these tests are vital for the success of this project. These tests not only evaluate the performance of the submarine, but also those of team members. During this semester, the tests are not only indoor. Testing was done in different locations, such as other College or University swimming pools, and diving facilities. It allowed the submarine to be evaluated in distinct underwater environments. Specifically, it allows simulating and recreating an ecosystem similar to the competition, such as adding obstacles, and being surrounded by natural elements (i.e. algae). Participating in a test means preparation, transportation, reservation and settling of equipment.

The most important tests were made to verify the new control algorithms. Without proper control of the submarine, the other goals are not achievable.

Some tests were done with a limited number of members due to lack of transportation means. However, the challenges allowed the team to work together and find solutions to cooperate and progress in the project.

More than 20 members are contributing their time for the accomplishment of S.O.N.I.A. It would not have come thus far without the dedication of passionate and hardworking students.

Acknowledgment

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