University of Victoria
AUVIC: Development, Design and Implementation of the "Kraken" AUV

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Abstract

Autonomous Underwater Vehicles Interdisciplinary Club (AUVIC) is an undergraduate student team from the University of Victoria. The team designs and builds autonomous underwater vehicles (AUVs) with the goal of competing in the RoboNation RoboSub competition, held at the the Woollett Aquatic Center in Irvine California. The main objective of the team is to give students the opportunity to apply the material learned in class to real world applications and experiment with projects outside of their main discipline. The club also offers students an opportunity to learn from others as well as teach others. These experiences translate to job opportunities and allows students to stand out when looking for co-op positions and employment after graduation. For a university located on an island, learning about underwater technology and underwater systems is particularly relevant and there are many associated careers.

Competition Strategy

AUVIC is competing this year with our AUV Kraken, which reuses some of the frame and plexiglass enclosures from the previous AUV, but many components of the submarine have been redesigned. The team competed last time in 2023, and we have identified some key areas that need improvement for this competition cycle:

- Unresponsive/static control system
- Minimal or no computer vision capability
- Inconsistent water-testing procedures
- Low-rate PID control implementation

This year, for RoboSub 2025, our main goal is to complete Collecting Data (gate) and Navigating the Channel (slalom). This will rely heavily on using our computer vision model to determine where posts are, with respect to the AUV. We have also been developing a dropper, torpedo launcher, and grabber in parallel. A reach goal would be to complete one of their associated tasks.

Design Strategy

The design strategy for this year's AUV consists of three main areas of interest: The software implementation, the electrical components, and the mechanical enhancements. Each section working together in harmony is vital to the proper functioning of the submarine.

A. Software:

The software for the Kraken AUV is run on the ROS2 Humble framework. This abstraction allows for greater control over separate processes and communication between them. The architecture is broken up into four ROS2 "nodes" which each run separately to perform necessary tasks for the AUV. The four nodes are the computer vision node, the state estimator node, the planner node, and the controller node.

The AUV's on-board computer must handle the inputs and outputs of several external devices. The following input devices to the AUV provide data about the surrounding environment:

- Depth sensor
- IMU
- Depth camera
- Bottom facing camera

The following output devices handle actions that the AUV must perform:

- Motor board
- Ball dropper
- Torpedo
- Grabber

Finally the AUV interfaces with the power board to regulate and manage power being supplied to different components.

Computer vision:
Computer vision is essential for navigating an underwater environment such as the course in the RoboSub competition. The Kraken AUV is equipped with two cameras to capture image data directly in front and below itself. The front facing camera that we selected has depth processing capabilities in order to provide a more holistic view of the AUV's surrounding environment. Image data from these cameras is piped into a computer vision model to determine what is in view of each camera as well as their relative positions and orientations with respect to the AUV. This data is then used to make decisions on movement and peripheral device activation, as well as providing more accurate location and orientation estimation.

State estimator:
While computer vision is necessary for determining the positions of objects around the AUV, we also need to know where the AUV itself is with respect to some reference frame. This is where our other sensors, the depth sensor and the IMU (Inertial Measurement Unit) come in. The depth sensor provides a global estimate of the depth of the AUV within the body of water that it is in, essentially providing the Z-axis of our estimation. The other axes are more difficult to estimate without error accumulation. The IMU provides both linear and angular acceleration and velocity, which can be used to calculate position and orientation. Since these values are derived, however, they will inevitably accumulate error, leading to possibly large discrepancies in the estimated position and the actual position. The relative positions and orientations of objects with respect to the AUV can be used to mitigate this. For example if the gate is in view of the forward facing camera and has not moved since the last frame, we can conclude that the AUV has not moved. Furthermore, since properties of objects within the course are known beforehand, these can be used to determine distances and relative orientations.

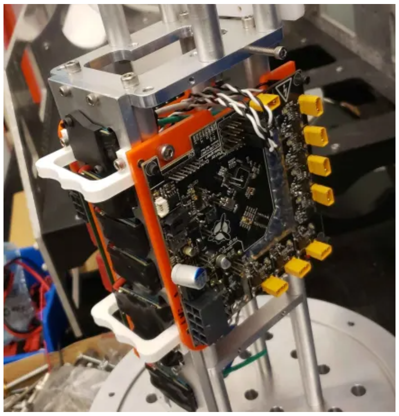
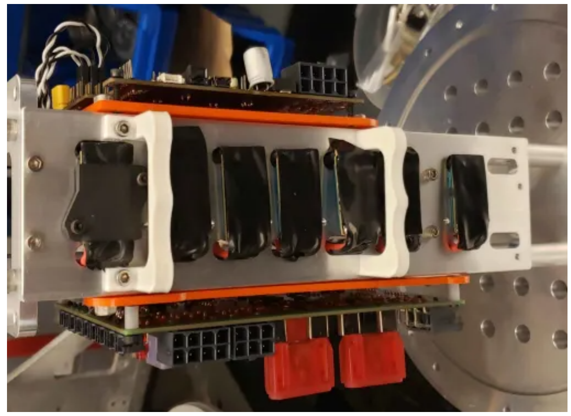
Planner Node:
The planner node is responsible for every high-level decision. It contains instructions listing the order in which actions must be taken to complete the course. These instructions, such as “move forward 2 meters” and “fire torpedo”, are contained in a finite state machine that encodes the next state based on certain success criteria. This success criteria can be if an object is within view of one of the cameras, or if the state’s action was successfully completed, or an error occurred. Each time the planner decides to execute another action, it sends a message to the controller node to complete the desired action. Once the controller node has finished the action or runs into an error, the planner decides what will be done next.

Controller:
The final node within the architecture is the controller node. This node takes information from each other node and sends commands to each of the output devices as required. The controller first gets an action from the planner node to execute. If the action is for one of the dropper, torpedo, or grabber devices to activate, then the controller will immediately send a command to the desired device and send a confirmation back to the planner. If the action is for movement, the controller will first note its current position, provided by the state estimator. Based on this position and the nature of the movement, the controller will determine the target position. With the current and target positions known, the positions will be fed into a PID loop to determine the speeds needed for each thruster in order to get the AUV to the target position. Once the AUV is at the target position (within a reasonable margin), the controller will send a confirmation back to the planner.

B. Electrical

In previous versions of AUVIC’s AUVs, electrical connections were mainly soldered wires connecting directly between boards and penetrators, so our main goal was to add modularity by adding connections so different electrical systems can be disconnected for testing and repairs.

Motor Controller & ESCs:
The motor controller board utilized a STM32 based microprocessor that controls eight Blue Robotics ESCs. This custom PCB board outputs PWM as well as the required regulated voltage for the ESCs. The ESCs also have a custom aluminum mounting board in the Kraken to help distribute the heat gain to keep the internal enclosure cool.

Figures 1 & 2: Motorboard mounting rig and ESC mounting configuration, respectively

Power Board:
The Power Regulation Board is the central power hub for all components on the submarine. The board controls and regulates the voltage of two 6S 22.2 Volt Li-Po batteries in parallel and distributes different regulated voltages required by different systems. The Power Regulation Board handles enough current to power the eight motors. It measures the current being drawn from both the batteries and by individual subsystems, and has the ability to connect and disconnect the batteries in parallel using control logic from the STM32F0. The board is fused to protect against short-circuits in any of the subsystems.

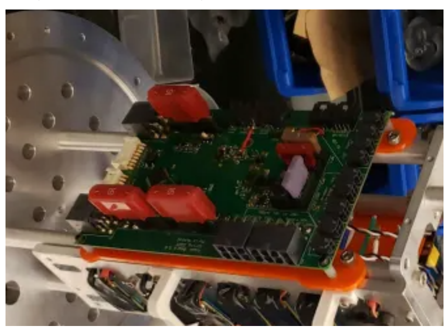


Figure 3: Powerboard mounting configuration

C. Mechanical

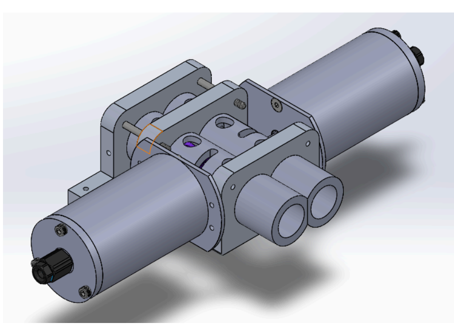
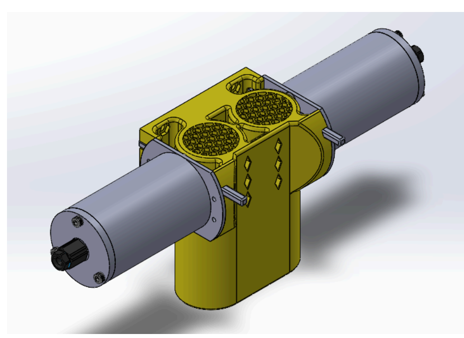
The 2025 team for AUVIC started with a large majority of new members to the club as almost every member from the 2023 competition team has graduated or moved on from the club. Because a previous AUV was left behind in Polaris, many aspects of that were transferred in the 2023 competition submarine Trident, which was used as a base for the Kraken before heavy modifications were made. From the Trident submarine, the main acrylic tube and aluminum side frames were kept, but not with some major modifications and remachining. The aluminum endcap was redesigned to allow for the needed connections to attach components not on Trident, such as a tether, ball dropper, torpedo and claw. The interior structure of the acrylic tube was re-designed to fit the new custom PCBs, ESC mounting board, new cameras and new Jetson computer. The frame was also modified to fit the new attachments and the tub was positioned further forward and lowered. This was done so there would be room to place the tube upright on new stands and take the acrylic cover off without having to disconnect the thruster wires, which is a major improvement from previous designs.

Manufacturing:
There was a lot of manufacturing to be done on the mechanical side this term, namely for modifications to fit the new and improved torpedo, claw and ball drop systems. With the new torpedo and ball drop release systems being powered by linear solenoids, we needed to make airtight enclosures to house them on the frame of the submarine. The frame of the AUV itself needed several modifications in order to fit new components. These changes were done with both functionality in mind as well as machinability.

Claw Mechanism:
The claw mechanism on the Kraken uses a grapple design powered by a motor with a lead screw attached. The lead screw can move in and out to adjust the position of the grapple. A future goal is to use camera vision to help air the movement of the claw.

Torpedo Mechanism:
The torpedo mechanism launches a 3D printed torpedo with an added metal rod for weight through a machined Delrin tube with an internal spring. The torpedo is controlled by our custom solenoid enclosure used on both the torpedo and ball dropper assemblies.

Ball Dropper Mechanism:
The Ball Dropper mechanism launches a 3D printed marker with added metal marbles for weight through a machined 3D printed tube. The torpedo is controlled by our custom solenoid enclosure used on both the torpedo and ball dropper assemblies.

Figures 4 & 5: new torpedo system and ball drop system designs, respectively

Testing Strategy

The largest challenge that we face as a team is our lack of testing facilities. The University of Victoria's McKinnon Pool was recently closed indefinitely, leaving our team without an affordable or accessible pool to test in. We have made efforts to find other facilities, however we still have very limited accessibility. With this barrier, we have decided to allocate more time and resources into developing a simulation model for the AUV. This new method of testing will provide us unlimited testing time and resources, at the cost of realism. This will be our main testing strategy moving forward until a reliable testing facility becomes available.

We are using the Gazebo simulation software to run our simulations and will interface with our ROS2 framework. The simulated model currently contains the thrusters, the depth sensor, and the IMU. These components are enough for testing the planner, a simplified version of the state estimator, and the controller nodes. More accurate physics and cameras will be added in the future. As for testing the computer vision node, images and video data can be fed into the model for training without the need for simulation, and simplified vision tasks can be added to the simulation in the future.

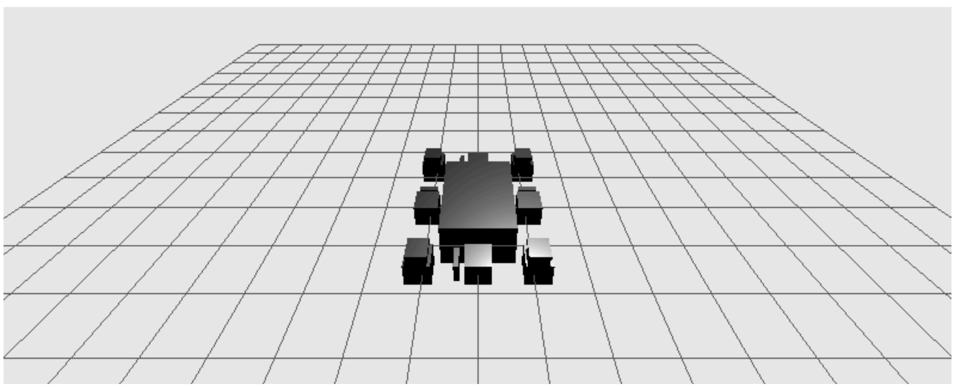


Figure 6: Model of the Kraken AUV within its simulated environment

Acknowledgements

The organizations that have helped make this year's participation in the competition possible, providing AUVIC with funds, materials, or expertise, are listed below:

- Co-operative Education and Work-Integrated Learning (CEWIL) Canada
  https://cewilcanada.ca/

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- Ocean Networks Canada (ONC)
  http://www.oceannetworks.ca/

ONC is AUVIC's partner company for the CEWIL project, and we appreciate their expertise in reviewing designs and overall support

- UVic Engineering Computer Science Students Society (ECSS)
  http://ess.uvic.ca/

The UVIC ECSS has helped fund AUVIC and other engineering clubs for both materials and travel to competition.