Design review for Vortex NTNU
08.11.23

Introduction
Our focus is to develop our student members to become good engineers and attractive candidates for the industry. We do this by creating Marine Robotics inspired by both the industry and institute and from new ideas that we can test through our collaboration with the industry.

Throughout the semester, Vortex have worked both technically and administratively to strengthen the organization from within. This is done through upgrading documentation and protocols to facilitate further development of both the Admin, Hardware and Software teams.

Terms which will be used:
ROV: Remotely operated vehicle
AUV: Autonomous underwater vehicle
USV: Unmanned surface vehicle
ASV: Autonomous surface vehicle

Contents

Goals

By prioritizing reliability and the integration of surface and underwater systems, Vortex aims to solidify our position in autonomous vehicle technology. In addition, we want to maintain our position as one of the leading student organizations at NTNU, to further attract the best students at NTNU to our organization.

Software Development Goals

Reliable Software Stack

The software team at Vortex aims to develop a robust and reliable software stack throughout the year. The team will prioritize deliverable-by-deliverable development, ensuring each part of the stack is functional and well documented at every deliverable. This approach not only ensures the proper functioning of the drone at the end of each deliverable, and quality documentation, but also reduces the challenges associated with our high turnover rate.

We can measure our progress by looking at the amount of reliable documentation that has been made and compare it with previous years.

Integration with Underwater Drones

Vortex's long-term goal is the integration of our surface vehicle with our underwater drone. This integration aims to explore the capabilities of our autonomous systems, opening new possibilities for exploration and data acquisition in various environments. In theory, we want to use Kongsbergs M3 Sonar to map the seafloor in order to locate pipelines and valves for our AUV to track, inspect and manipulate.

Hardware Development Goals

New AUV Design

The hardware team is committed to designing and developing a new Remotely Operated Vehicle (ROV) with enhanced capabilities. This ROV will serve as a versatile platform that can easily be adapted into an Autonomous Underwater Vehicle (AUV) in the coming years. The focus is on optimizing the hardware architecture to accommodate for integration with our surface vehicle, while maintaining its underwater functionalities.

Autonomous Surface Vehicle Improvement

Simultaneously, the hardware team is dedicated to enhancing the Autonomous Surface Vehicle (ASV). Collaborating closely with the software team, electrical engineers will implement improvements to the vehicle's sensors, actuators, and overall design. The mechanical team will also install a Kongsberg M3 sonar on the ASV.

Marketing

This year, we want to focus on maintaining good external relations, and look further into how we market the organization externally. We believe that our non-formal approach to marketing makes the organization more approachable for students and makes it easier for the people interested to apply.

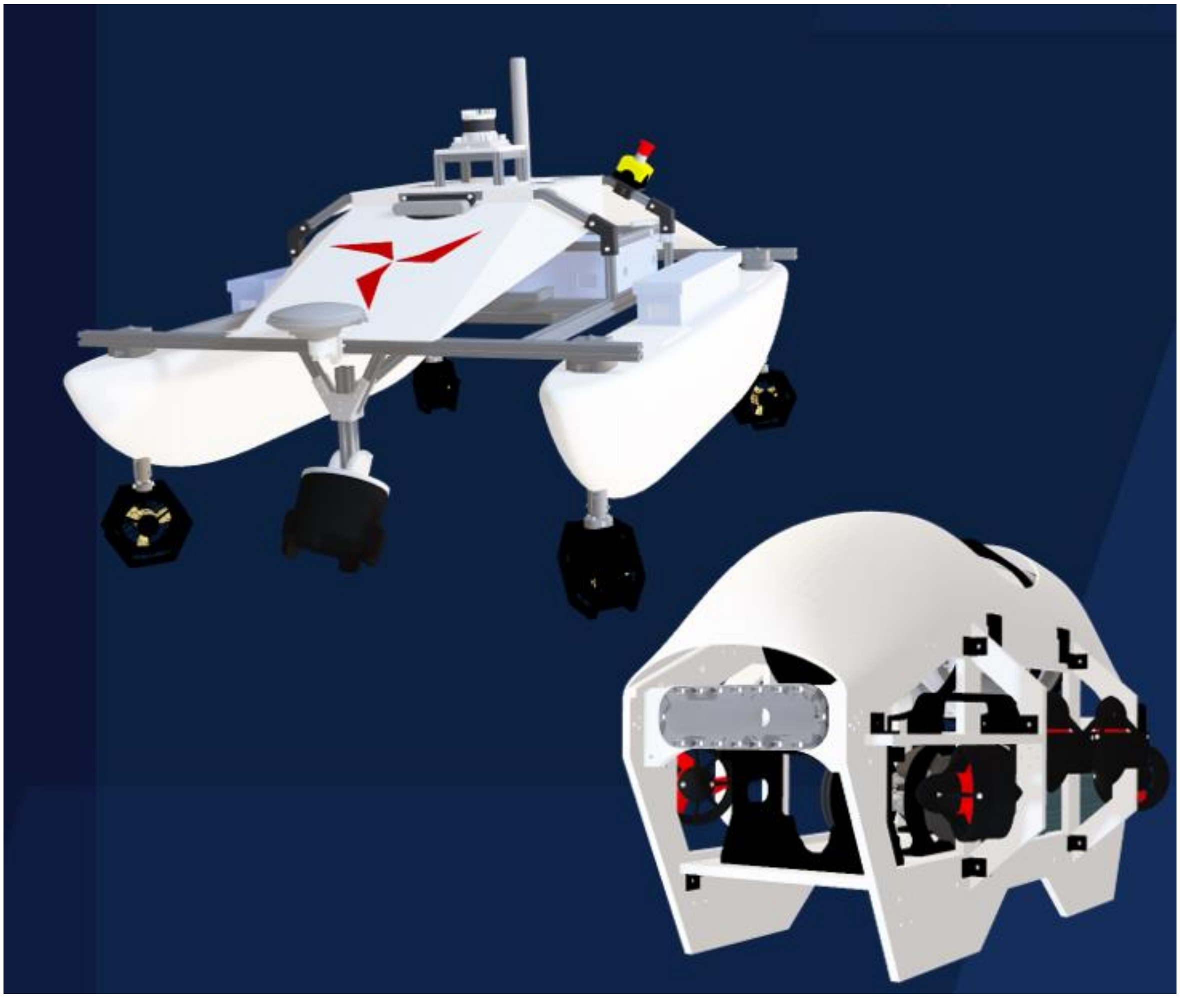
The way we do this is to focus on social media, specifically Instagram. Here, we can reach our preferred audience better. We do this by focusing on stories and Reels. The algorithm is always pushing the newest release, and by using stories, we can automatically create reels created by Instagram stories. Since Reels is Instagrams latest release, we hope to get our content pushed to potential new members.

In addition to our social media focus, we have also investigated ways of streamlining our recruitment on campus. We have investigated easier ways to bring our equipment to stands (our vehicles rely on cars to get around). Our mentors have made mini-models of our vehicles, this way we can showcase and present our work without having to bring all the large and heavy equipment.

Our graphic profile got a big upgrade last year, and we wish to supply this with new vehicle stencils. We have also created a new system for content sharing and organizing through Google pictures. This seems to work really well, since it is easy to use and easy to maintain.

Last on the marketing agenda, we want to further bring sponsors in on what we do. This is done through reports from triweekly, concept reviews and design reviews.

Hardware



Mechanical

Problems from Earlier Years:

ASV:

1. **Not Enough Buoyancy:**
    - Addressing this issue requires exploring several solutions, such as water cooling, using a metal base plate as a heat sink, adding a water-cooled plate under the el-house, or employing a full metal el-house.
2. **Possibly Overheating El-Housing:**
    - Potential solutions include implementing water cooling, using a metal base plate as a heat sink, adding a water-cooled plate under the el-house, or constructing a full metal el-house.

AUV:

1. **Heavy and Unstable:**
    - The AUV is too heavy and stable for effective task performance.
2. **Buoyancy Balancing Challenges:**
    - Achieving the right buoyancy balance proves difficult, impacting overall performance.
3. **Inefficiency in Strong Currents:**
    - The AUV faces challenges operating in strong currents.
4. **Unreliable Pneumatic System:**
    - The current pneumatic system is not reliable, affecting the AUV's functionality.
5. **Difficulty in Launching:**
    - The AUV is hard to launch, affecting deployment efficiency.
6. **Integration Issues with ASV:**
    - The AUV's size poses challenges for seamless integration with the ASV.

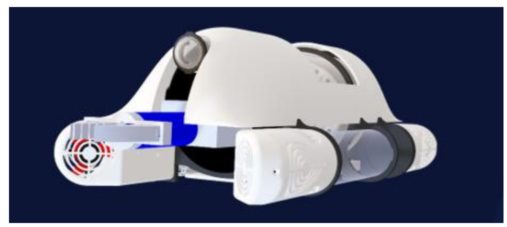
Work Done and Possible Solutions:

1. **Sonar Mount:**

   - Utilizing aluminum profiles and 3D-printing, the sonar mount allows for adjustable angles.

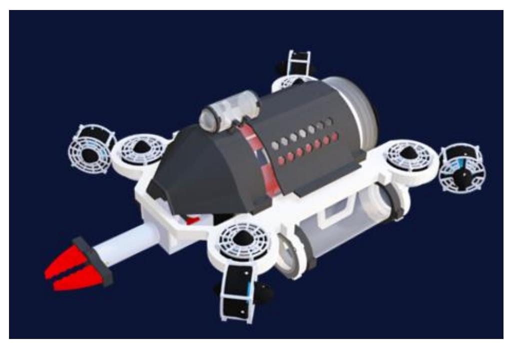
2. **Buoyancy:**
   - Considering kayak stabilizers as a potential solution for buoyancy issues.

3. **Frame Concept 1 for the New Drone:**



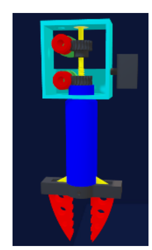
   - A lighter and slimmer design compared to the Beluga, with improved agility and balance.
   - Integration with the ASV is a key consideration, involving the production of POM plates connected by aluminum profiles and a 3D-printed shell.

4. **Frame Concept 2 for the New Drone:**



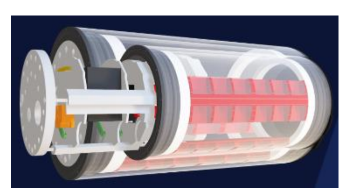
   - Improved thruster placement and high camera positioning for enhanced design.
   - Incorporates a clamping system for battery modules, buoyancy adjustment, and a payload attachment point.
   - Thrusterguards are added to protect against seaweed.

5. **Gripper Design:**



   - A gripper with three degrees of freedom to complete valve tasks in the TAC Challenge.
   - Utilizes a worm gear mechanism, with 3D-printed parts and metal gears.

6. **El-Housing on AUV:**
   - The el-housing is redesigned as a modular assembly with threaded rods, using 3D-printed PETG plates for component discs.



Conclusion:

The development of ASV and AUV systems involves addressing various challenges from previous iterations. The outlined solutions and ongoing work demonstrate how we are working on enhancing buoyancy, stability, and overall efficiency in our underwater vehicle operations.

Mechanical Design Q&A Session Summary:

Q1: Is there redundancy for connecting the sonar in case the bracket breaks?

- A1: The sonar is attached by the cable, and a metal wire will provide additional security. A zinc anode will be added to prevent corrosion, and a longer rod for height adjustment. Audience tip: KD website provides a mounting guideline.

Q2: Why have extra pontoons on the inside and not the outside?

- A2: Extra pontoons are placed on the inside to comply with Njord rules.

Q3: How do enclosed thrusters affect agility?

- A3: Enclosed thrusters won't directly impact agility; the new layout will. Enclosed thrusters are prioritized to avoid seaweed issues, even if it affects thrust output.

Q4: How will you remove the el-house from the new drone?

- A4: The back lid is easily removable, and the el-house will slide out.

Q5: Is there room for last-minute expansion in the el-house?

- A5: The el-house isn't designed for last-minute changes, but there is some extra space.

Q6: Have you considered a closed-loop cooling system?

- A6: Just starting to explore the issue; considering the tip for a DI-water cooling system. Audience tips: Dip radiator into the sea, use aluminum or copper, preferably water cooling over air, clean system after each sea test, metal casing is easier, plastic is fine if it transports heat.

Q7: In concept 2, with the camera high up, can you see the gripper?

- A7: A second camera will be added to observe the gripper.

Q8: How is max clamping force handled to ensure safety?

- A8: Safety measures not fully explored yet. Gripper can't close completely, preventing the risk of trapping fingers.

Electrical

Electrical Problems from Previous Year:

1. **Unreliable and Sensitive Systems (Freya and Beluga):**
   - Focus on robust solutions, eliminating human error causes.
   - Rigorous testing and verification of system functionality.
2. **Issues with Power Distribution Board (PDB) and PreCharge Systems:**
   - PreCharge Systems: Equalizes voltage before connecting relays.
   - Power Distribution Board: Reduced size, smoothing current input to PDB.

PreCharge Systems:

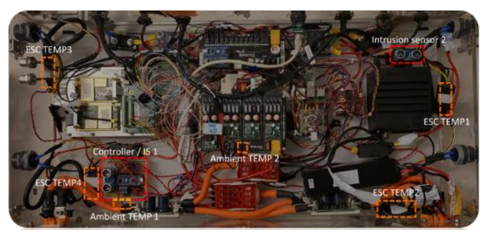
- Ensures gradual voltage equalization before relay connection.

Power Distribution Board:

- Size reduction and current smoothing for improved efficiency.

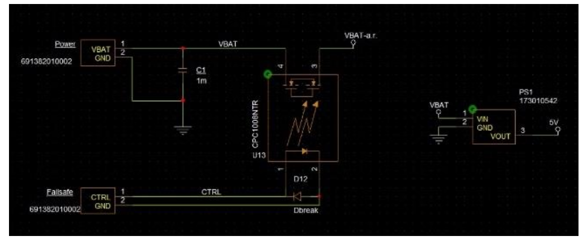
ASV Projects:

1. **Acoustics Board:**
   - Hydrophones capture sound waves.
   - Information extraction and instrumental amplification with buffer and differential input.
   - Inclusion of a Low-Pass filter.



2. **Failsafe Upgrade:**
   - Transition to ATMEGA 2560 16AU from 2 Arduino Nanos.
   - Integration of temperature sensors, fuses, and pre-charge systems.

3. **ESCs for Thrusters:**
    - Addressing issues of burnt ESCs and induced power during thruster output switching.
    - Addition of smoothing capacitors to absorb voltage spikes.



ESC

4. **Temperature Sensing in Freya's El-House:**
    - Utilization of NTC resistors for measuring ESC and ambient temperatures.
    - I2C reporting of temperature data.
5. **Lid On/Off Detection:**
    - Detection of el-house lid status with a warning beep if the lid is off, for safety reasons.

New AUV:

1. **New El-House:**
    - Requires rewiring and restructuring for enhanced modularity.
    - Incorporation of a Battery Management System (BMS) using LiPo batteries, BM3451 Cell battery protectors, and a custom-made BMS with an ordered breakout PCB.
2. **Custom Subsea Gripper:**
    - Utilizes brushless DC motors, servo motors, and PWM controls.
    - Potential for autonomous control with Hall-effect sensors.
3. **New Cameras:**
    - Integration of Blackfly S GigE cameras with PoE connectors.
4. **AUV Failsafe Enhancement:**
    - The existing system cuts power to thrusters when a magnetic switch is removed.
    - Improved design incorporates Hall-effect sensors and a potentiometer for manual adjustment.

Conclusion:

The enhancements in the power distribution board and precharge systems contribute to the overall operation stability of the drones. Notably, the incorporation of failsafe measures, temperature sensing, and lid on/off detection in the ASV projects showcase a commitment to safety and system integrity.

The development of a new AUV introduces significant advancements, including a redesigned el-house for increased modularity, a Battery Management System (BMS), and a custom subsea gripper with autonomous control capabilities. The integration of Blackfly S GigE cameras and improvements to the failsafe mechanism further highlight the team's pursuit of safety measures and integrating new technology.

Electronics Q&A Session Summary:

Q1: With the switch to ATMEGA, you have half the processing speed. How will you handle it?

- A1: Processing power isn't fully utilized. Priority is on obtaining more pins. The new system can handle the load due to its simplicity.

Q2: The BMS chip seems sketchy. Any concerns?

- A2: Challenges in finding a suitable chip. The chosen one offers more functionality for their use, and they believe it will work fine. Tip: Suggested looking into TI for alternatives.

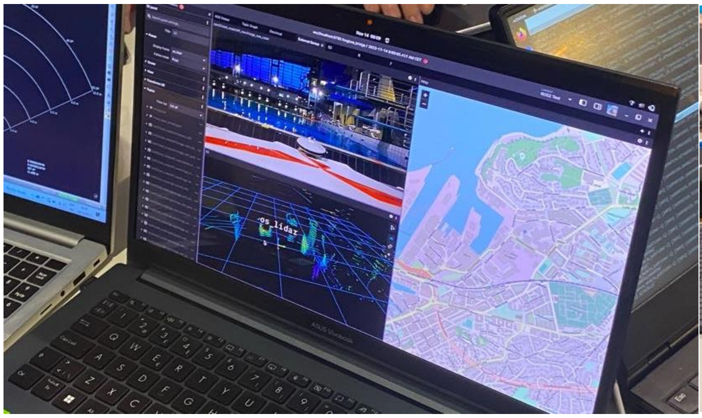
Q3: Can the precharge be digital with an Arduino instead of analog?

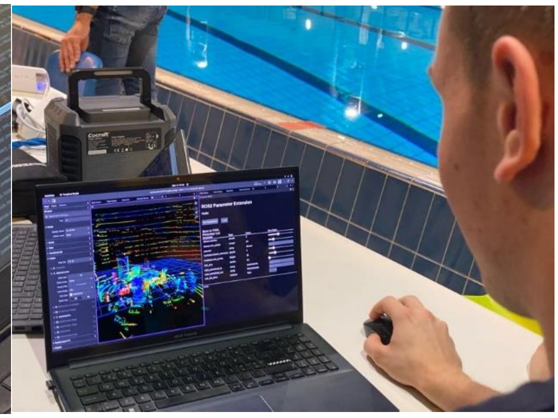
- A3: Exploring options, including finding an ADC that supports the load.

Q4: Acoustics board – starting from scratch or continuing from the old board?

- A4: Opened the old schematic but found it messy. Decided to start anew, using the old one as inspiration. Bought a pre-made board; digital side can be copied, but the analog side needs to be crafted from scratch. Tip/Offer: KD offers a design review with their designers if needed.

Software





Embedded

Power Distribution:

- **Freya's Power Sense Module (PSM):**
    - Data transmission to rasPI and publishing to a ROS node.
    - Long-term objective: Develop a black box for comprehensive data analysis in case of failures.

Thrusters:

- Temperature measurement at various points.
- Conversion of sensor data to temperature.
- Data transmission via I2C.
- Publication of temperature data.

Batteries:

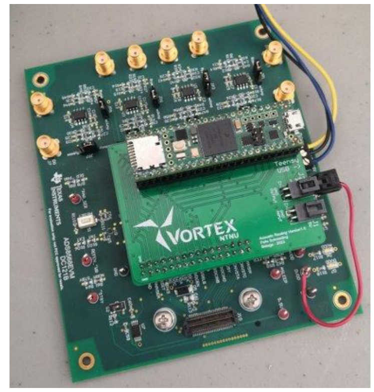
- Implementation of a Battery Management System (BMS) data logger.
- Publication of data to the environment.
- Emphasis on a clean implementation with thorough documentation, essential for competitions.

Failsafe System:

- Recognition of complexity with multiple microcontrollers from various contributors.
- Focus on creating a simplistic, easy-to-maintain design.
- Coordination of simultaneous operation to avoid conflicts.
- Implementation of temperature level logic to regulate thruster power based on temperature.
- Code refinement, replacing "if-else" structures with a cleaner "switch" logic.

Acoustics Summary:

- Objective: Collect extensive data and enhance system robustness, reliability, and usability.
- Development of acoustics involves leveraging an ADC developer kit.
- Sampling capabilities extended up to 70 kHz, exceeding the competition requirement of 50 kHz.
- Incorporation of Digital Signal Processing (DSP) techniques.
- Data transfer considerations, including compromises in interrupts, Ethernet + UDP communication, connection strategies, and robust data flow solutions.
- Current challenges in the robust data flow solution necessitate ongoing refinement.



Next Stage:

- Planned development of a tailored acoustics PCB by the electronics team.
- Exploration of the Time Difference of Arrival (TDoA) concept.

Conclusion:

Our embedded team has made significant progress in power distribution, thruster management, battery monitoring, failsafe implementation, and acoustics development. The integration of the Power Sense Module (PSM) in Freya, coupled with data transmission and ROS node publication, marks a step towards creating a comprehensive black box for system analysis in case of failures.

Thruster temperature monitoring, utilizing I2C for data transmission and publication, enhances our understanding of thruster conditions. The Battery Management System (BMS) data logger, with its clean implementation and meticulous documentation, aligns with competition requirements and ensures reliable battery performance.

Recognizing the complexity of the failsafe system, efforts are focused on creating a simplistic, easy-to-maintain design that coordinates seamlessly. Temperature level logic and code refinements contribute to enhanced reliability and efficiency.

Our approach to acoustics centers on collecting extensive data, improving system robustness, and ensuring ease of use. The development of acoustics involves techniques including an ADC developer kit, exceeding competition requirements in sampling, and addressing challenges in data transfer with ongoing refinements.

Embedded Systems Q&A Summary:

Tips:
Ensure continuous sampling during data shipping; misconfigurations may hinder this, and the DMA controller is complex.

Q1: Why the handshake at the beginning, why not just send data?

A1: The aim is to obtain different types of data. The approach is to send all data initially and then select specific data as needed.

Tips:

Caution against assuming superiority over the compiler; there's no difference between "if-else" and "switch" as the compiler handles it efficiently.

A2: Why use "switch" instead of "if-else"?

A2: Personal preference; "switch" appears more comprehensible and easier to work with and understand.

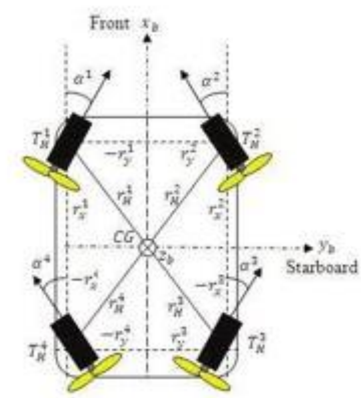
Autonomous

Joystick Interface:

- *Interpretation of XBOX Controller Inputs:* Implementation of a system to interpret inputs from an XBOX controller, subscribing to inputs from the joystick driver to the Xbox controller.
- *Software Stack Update to ROS2:* Ongoing efforts to update the software stack to ROS2, ensuring compatibility with the latest robotic operating system standards.

Thruster Allocation:

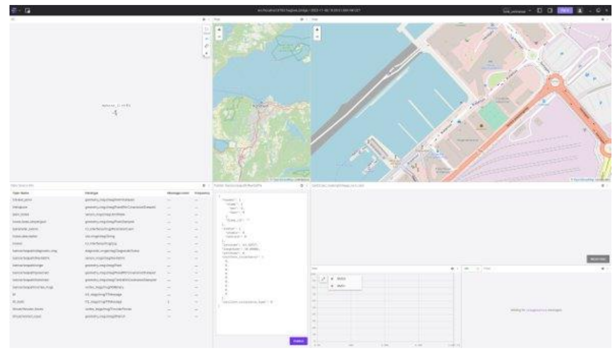
- *Calculation of Thruster Forces:* Determines the forces required for each thruster.
    - Subscribes to wrench messages from the joystick interface.
    - Utilizes a configuration matrix for allocation calculations.
    - Performs a pseudo-inverse calculation due to Freya's over-actuated nature.
    - The matrix is applied to multiply by wrench messages.



- *Output Thrust Publication:* Publishes the calculated output thrust, subsequently converted to PWM signals.
- *Pending Implementations:* Future steps involve integrating an LQR controller and a path-following algorithm for comprehensive thruster control.

Seapath Driver:

- *ROS 2 Update:* Initiation of the update process to ROS 2 for the Seapath driver.
- *Functional Enhancements and Changes:*
    - Addition of functions such as resetting the origin point.
    - Inclusion of new publishers, specifically for error and warning messages.
    - Removal and fixing of functions for optimized performance.



- *Upcoming Tasks:* Focus on integrating an interface and visualizing thruster output within Foxglove Studios to enhance monitoring and diagnostics.

Conclusion

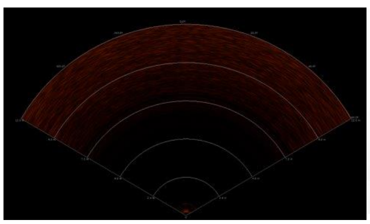
The transition to ROS 2 ensures compatibility with modern robotic operating systems, while continuous improvements in the Seapath driver expand functionalities and provide valuable diagnostics. The integration of an LQR controller and path-following algorithm in the thruster allocation system remains a priority for future development, ensuring precise and efficient control in various operational scenarios.

Situational Awareness

The primary goal is to integrate Lidar, Sonar, and Camera systems on Freya, with a specific focus on upgrading the entire setup to ROS2 (Robot Operating System 2).

Current Status:

- Lidar: Successfully operational during the last testing phase.
- Camera: Functioning similarly, with a ROS2 wrapper in place. Zed camera ROS2 wrapper is operational, although it demands considerable processing power. Initial attempts at docking were suboptimal.
- M3 Sonar: Tested with the M3 device, but encountered challenges with data comprehension. Minimal or no changes in data during movement were observed.




Communication Infrastructure:

- Completion of the communication client-server (API) to facilitate interaction between devices.
- Challenges faced include API compatibility for Windows and two Linux devices, as well as latency concerns. Explorations were made for a direct connection to Seapath.

Point Cloud Processing:

- Initiated point cloud processing with the development of a ROS2 node for Point Cloud Library (PCL) processing.
- Utilization of downsampled PCL for further analysis.

Struggles and Challenges:

1. **API Compatibility:** Adapting the communication API to function seamlessly across Windows and two Linux devices presented challenges.
2. **Latency Issues:** Addressing latency concerns in the communication infrastructure proved to be a noteworthy challenge.
3. **Sonar Data Interpretation:** Difficulties arose in comprehending data from the M3 Sonar, particularly with minimal changes during movement.

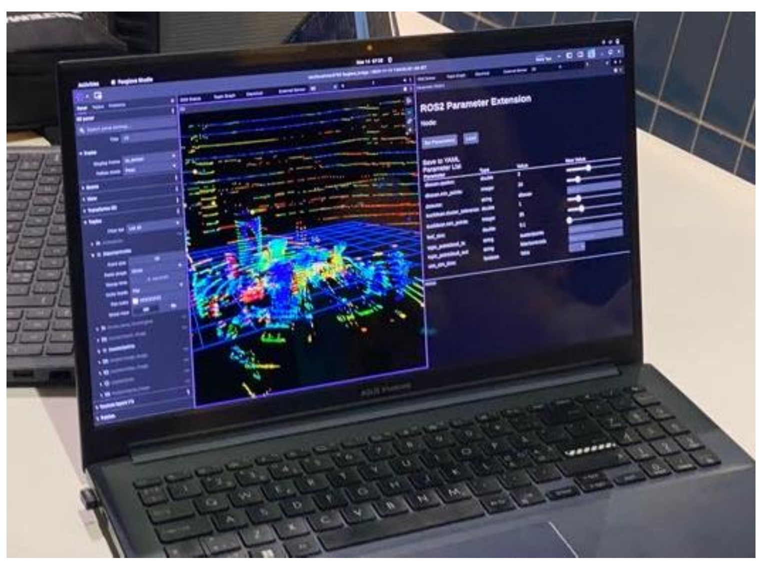
4. **Docking Attempts:** Initial attempts at docking using the Zed camera wrapper encountered challenges and require further optimization.

Next Steps:

- Refinement of the communication infrastructure to mitigate latency issues.
- Further exploration and optimization of the Zed camera wrapper for improved docking capabilities.
- Continuous testing and improvement of the M3 Sonar data interpretation for enhanced understanding during movement.

Conclusion

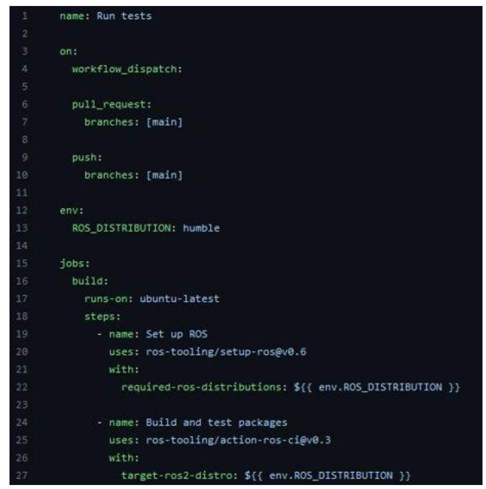
Challenges, particularly in communication and sonar data interpretation, are actively being addressed. The transition to ROS2 signifies a commitment to the latest technologies and a robust foundation for future developments in autonomous surface vehicles.



DevOps

CI/CD Integration:

- *Unit Tests:* Implementation of comprehensive unit tests for ROS, utilizing Pytest and gtest.
- *Test Environment:* Utilization of the colcon test environment to execute a diverse range of tests stored in the designated test directory.
- *Attribute Import:* Incorporation of a function attribute from a location external to the current repository.



```yaml
name: Run tests

on:
  workflow_dispatch:

  pull_request:
    branches: [main]

  push:
    branches: [main]

env:
  ROS_DISTRIBUTION: humble

jobs:
  build:
    runs-on: ubuntu-latest
    steps:
      - name: Set up ROS
        uses: ros-tooling/setup-ros@v0.6
        with:
          required-ros-distributions: ${{ env.ROS_DISTRIBUTION }}

      - name: Build and test packages
        uses: ros-tooling/action-ros-ci@v0.3
        with:
          target-ros2-distro: ${{ env.ROS_DISTRIBUTION }}
```

Revisited Docker Publish Workflows:

- *Single Docker File:* Streamlining the image-building process by creating an image from a single Docker file.
- *Repository Package Publication:* Automatic publication of the repository package.
- *Commit SHA as Image Tag:* Adoption of the commit SHA as the image tag for enhanced version control.

Docker Integration:

- *Containerized ROS Experimentation:* Exploration of containerized ROS for improved modularity and flexibility.
- *Talkers and Listeners:* Implementation of talkers and listeners within the Docker environment.
- *Support for SITAW:* Assisting SITAW with their ROS-related challenges within the Docker ecosystem.

Ongoing Tasks:

- *Cellular Connection Integration for Freya (ASV):*
  - Investigating methods to integrate cellular connections, specifically 4G, to enhance system redundancy.
- *Automated Factory Acceptance Test for Freya:*
  - Implementation of a YAML-based automated Factory Acceptance Test (FAT) for Freya.
  - Frequent updates and continuous maintenance to accommodate evolving requirements.
  - Generation of a comprehensive report on the drone's condition to gather valuable feedback.

Conclusion

Ongoing tasks encompass critical aspects such as cellular connection integration for redundancy on Freya and the development of an automated Factory Acceptance Test, both contributing to the continuous improvement of our autonomous surface vehicle systems.