Autonomous Underwater Vehicle Adaptive Sampling for Source Localization

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Introduction

In the development of new technologies, testbed class vehicles play an important role allowing for new designs to be tested in controlled, low stakes environments. The design team was provided with a Riptide AUV as a testbed class vehicle, to develop an autonomous adaptive sampling behavior for integration with a nitrite sensor to localize a source.

Project Scope

1. Integrate the Nitrite payload sensor into the body of the AUV
2. Design an autonomous sampling capability
3. Implement the autonomous sampling capability using the Robot Operating System (ROS) framework
4. Enable commination between the ROS software architecture and the AUV native operating software MOOS-IvP.
5. Integrate the payload processor into the AUV
6. Perform incremental testing for system validation

Design Process

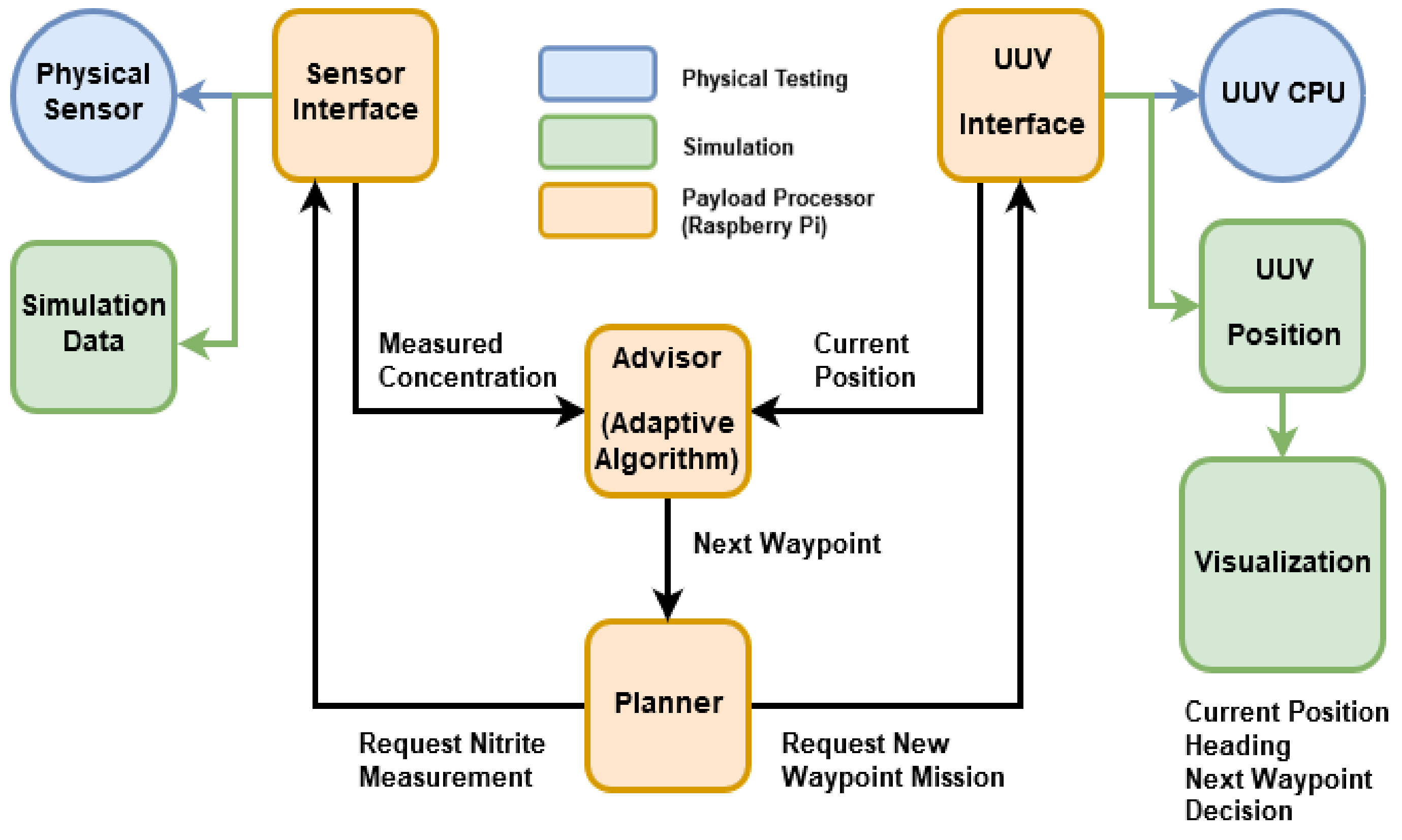

Figure 1: Overview of system architecture and interaction between the Physical, Hardware, and Simulation systems

The design can be broken into smaller parts consisting of physical integration, payload processor software architecture, and simulation. In physical integration, a mounting system to accommodate the payload processor was created and all necessary wiring extended to facilitate physical connections. Significant design was completed constructing the software architecture in ROS allowing for communication between the sensor, UUV and adaptive algorithm.

Physical Integration

The system was designed to allow for the incorporation of a variety of sensor packages with the ultimate goal of integrating the "lab-on-a-chip" technology being developed by Seiben Lab. For testing, a photodiode colour sensor was used as a placeholder for the nitrite sensor being developed. The final design achieved the following:

- Integrated a pre-existing sensor package
- Utilized standard mounting flange and hardware
- Immersed sensor face allowing direct water ingestion
- Maintained positive buoyancy
- Implemented pressure testing capabilities to the AUV
- Vacuum pressure tested to 6 meters depth equivalent
- Extended power and communication wiring

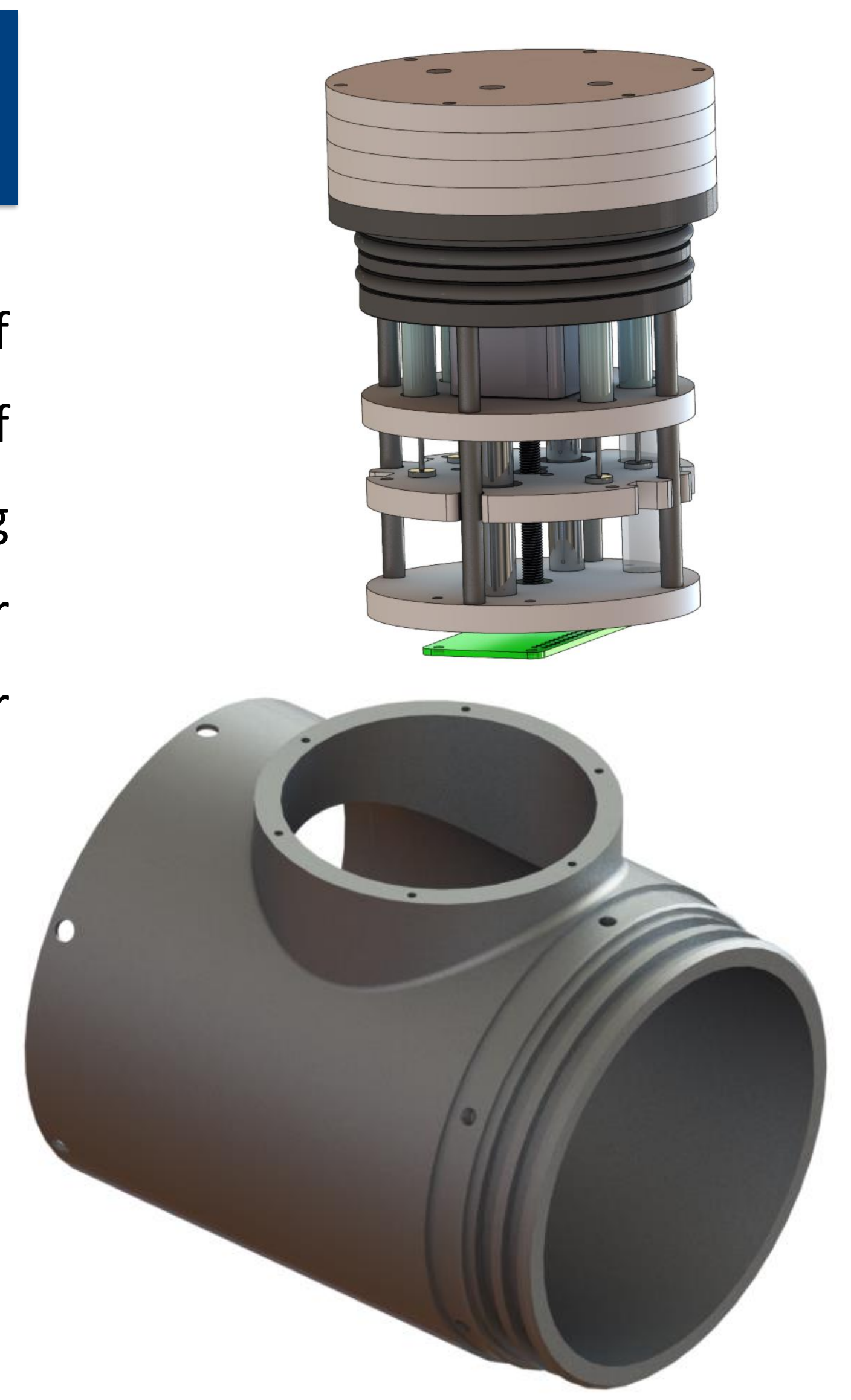

Figure 2: The nitrite sensor from Sieben Lab [1] interfaces with a blue robotics case and the aluminum accessory ring created by the group

Figure 3: Riptide produces a testbed class vehicle which has approximately 35 hours of battery life.

Testing

Five testing sessions were completed at Dalhousie's Aquatron tank which allowed for testing of the vehicle control using MOOS-IvP. The vehicle was able to effectively reach waypoints set through the planner. The testing was undertaken to determine the limitations of the operating system and vehicle.

Figure 6: The team deploying the riptide within the Aquatron to test controls via MOOS mission files.

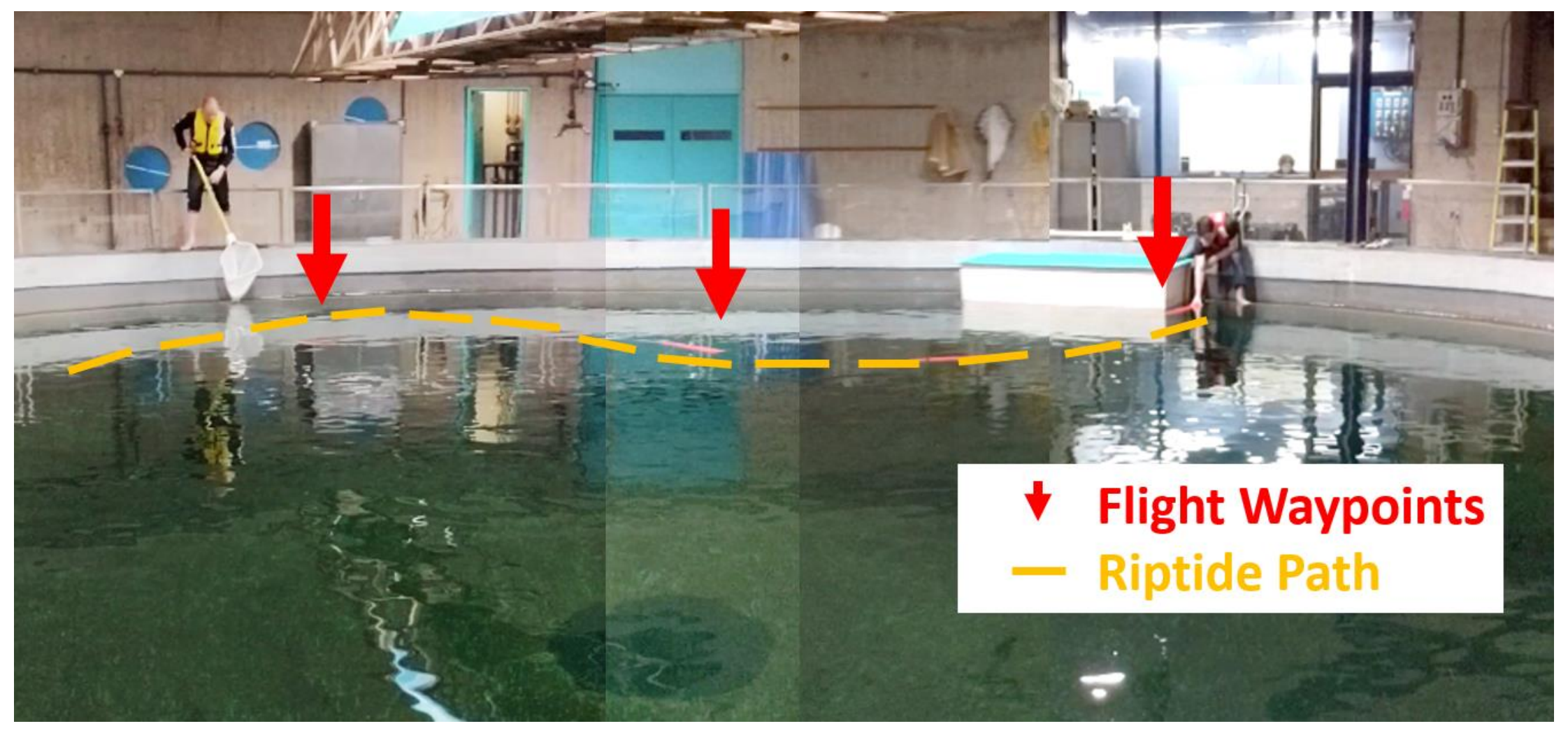

Figure 7: Experimenting with waypoint behaviors

Frequent progressive lab-desk hardware integration tests, in addition to the Aquatron tests, showed that MOOS system waypoints could be set using the autonomous behaviour implemented in ROS.

Autonomous Behaviour

The vehicle aims at interpreting the environment through limited spatial and temporal sampling. After 4 measurements, the algorithm:

1. Creates a linear approximation of the nitrite field in the form:

$$Nitrite\ Concentration = N = \beta_0 + \beta_1 x + \beta_2 y + \beta_3 z$$

$$\begin{bmatrix} 1 & x_0 & y_0 & z_0 \\ 1 & x_1 & y_1 & z_1 \\ 1 & x_2 & y_2 & z_2 \\ 1 & x_3 & y_3 & z_3 \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} = \begin{bmatrix} n_0 \\ n_1 \\ n_2 \\ n_3 \end{bmatrix}$$

$$A\beta = N$$

2. Finds the coefficients of the plane using least squares approximation: $\beta = (A^T A)^{-1} A^T N$
3. Finds the gradient or direction to the highest nitrite concentration of the plane:

$$\left(\frac{\partial N}{\partial x}, \frac{\partial N}{\partial x}, \frac{\partial N}{\partial x}\right) = (a_1, a_2, a_3)$$

4. Decides the next waypoint by moving along the gradient from the current position.

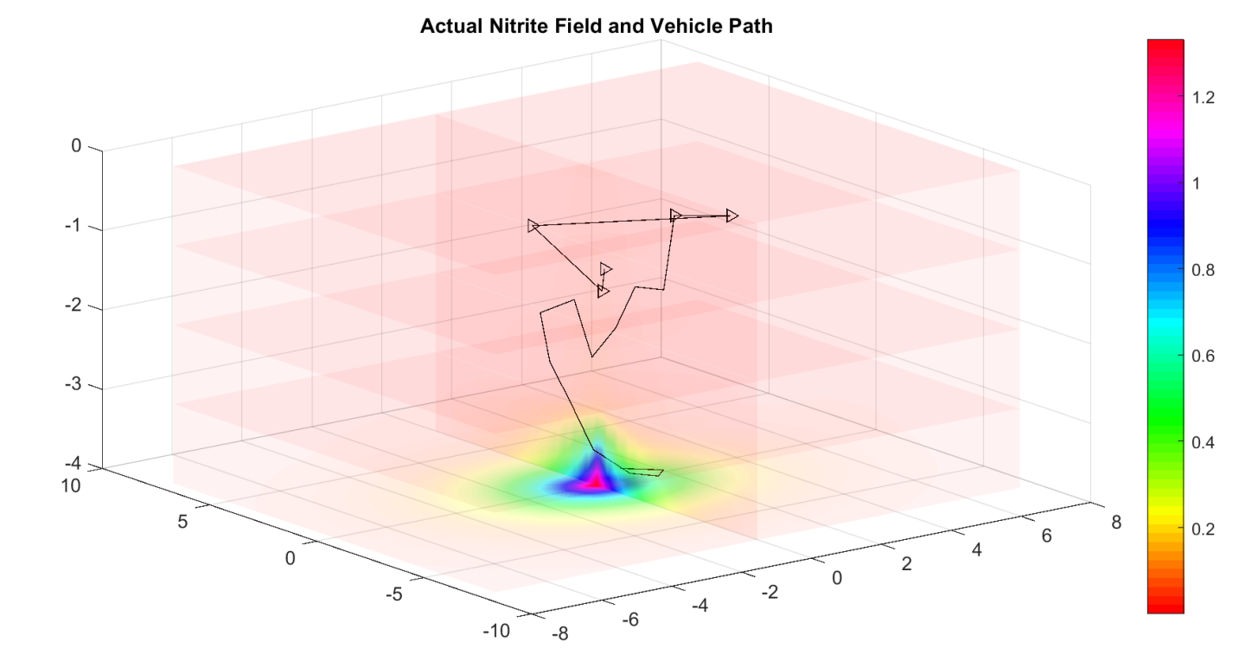

Figure 4: Matlab was used to test the gradient descent algorithm and display the vehicle path

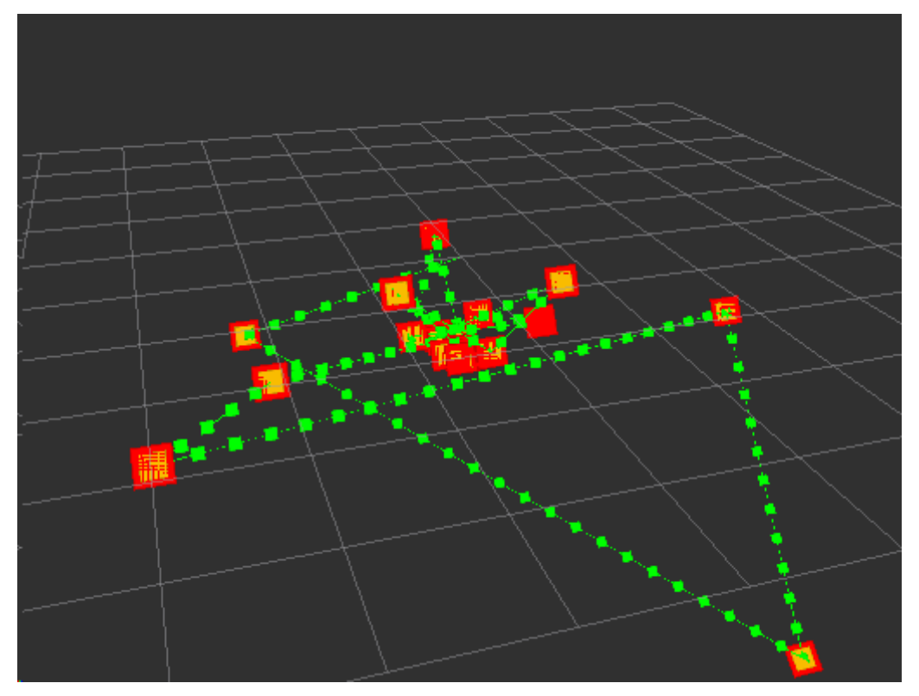

Figure 5: A simulation was created within ROS architecture to test the entire system

Conclusions and Recommendations

- Waypoints can be generated during flight autonomously using live sensor measurements
- Accommodations for future sensor integration were created to allow for a variety of sensor packages to be installed using standardized hardware
- Further testing in a larger tank is required to gain full understanding of vehicle flight capabilities

References and Acknowledgements

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[1] SiebenLab, Correspondence with Dr. Sieben, H. D'Alesio, R. Khosravi, S.Morgan, Halifax, 2018.

Riptide Autonomous Solutions, "Mk II micro UUV User Manual," Riptide Autonomous Solutions, Plymouth, 2018Z

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