Autonomous Underwater Robot for Water Quality Measurement of Northwest Pennsylvania Lakes

Pallas-Athena Cain, Trang Hoang, Janyl Jumadinova
Allegheny College
520 N. Main Street, Meadville PA 16335
{cain01, hoang01, jjumadinova}@allegheny.edu

Abstract

The Northwestern Pennsylvania Region, notably affected by toxic algae blooms like those in Lake Erie, suffers from a lack of adequate water quality monitoring tools. This project aims to bridge this gap through the development of cost-effective underwater robots designed to gather critical water quality data. The software developed for this project facilitates the generation of analytics essential for assessing the health of aquatic environments. The robots engineered through this project are set to be deployed by the local Conservation District for routine water quality monitoring activities.

Water Monitoring

Our team developed an automated underwater robot equipped with various sensors for comprehensive water quality assessment. This initiative addresses the urgent need for continuous and detailed water quality monitoring to detect contaminants and track harmful algal blooms (HABs), which pose significant threats to both ecosystems and human health by causing marine life die-offs and various illnesses in humans (Grattan, Holobaugh, and Morris Jr 2016; Paerl et al. 2019). The capability to gather extensive water quality data enables the implementation of targeted mitigation strategies, crucial in areas like northwestern Pennsylvania, where resources for such monitoring are often scarce.

Traditionally, our local Conservation District has performed manual water quality assessments in local lakes, employing a methodical approach by lowering sensors from boats at different depths and locations. This process, aimed at measuring water quality across depth gradients of 15 to 30 feet, has been labor-intensive and limited in scope.

Our project sought to enhance and streamline this process by creating a mobile robotic system capable of simultaneous and autonomous data collection across multiple sites. This system not only facilitates efficient water quality testing but also supports the community in our county by offering a tool for advanced monitoring and analysis of algal proliferation, thereby contributing to environmental preservation and public health efforts.

Copyright © 2024 by the authors.
This open access article is published under the Creative Commons Attribution-NonCommercial 4.0 International License.

Robot Design

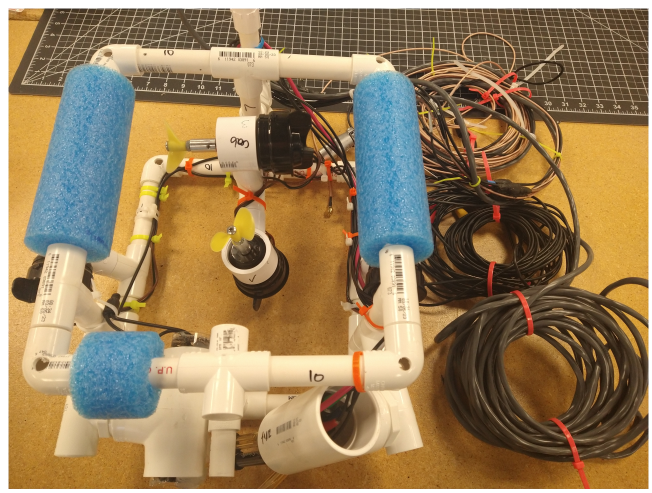

Figure 1: Robot construction

Our underwater robot design utilizes components from SeaMATE (Moore et al. 2010), including a control system, motors and propellers, cameras, power and tether. The construction of our robot's frame employs PVC pipes of 1/2 inch and 3/4 inch diameters. To ensure water resistance, cameras are housed within acrylic tubes and sealed with epoxy. The buoyancy control system incorporates modified household pool noodles to achieve neutral buoyancy, a critical factor for the robot's maneuverability in water. The attachment of sensors to the remotely operated vehicle (ROV) utilizes zip ties, connecting them to the control box via the ROV's tether. A 50 ft. tether cord links the robot to the control box, which receives power through an Anderson power pole connector, supplying between 13.5 and 14 volts. The adoption of a portable power generator expands the operational range of the ROV beyond the limitations imposed by the availability of electrical outlets. The robot is constructed to execute four distinct types of movement: surge (forward propulsion), heave (vertical movement), yaw, (robot's directional orientation) and sway (lateral movement).

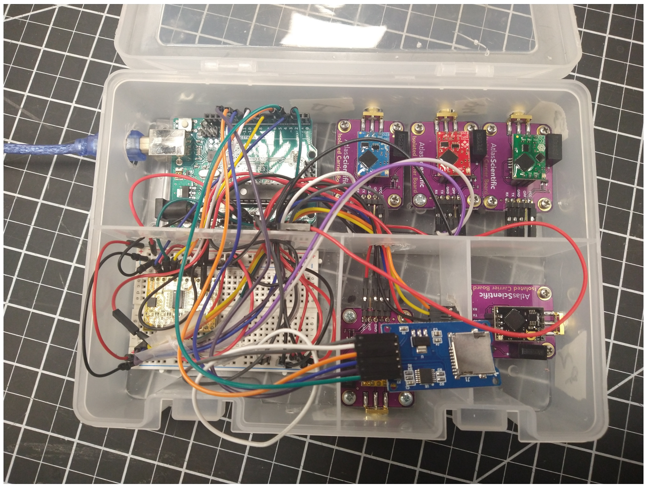

Figure 2: Sensors used in the robotic system

Automation

The initial design of the robot featured a remotely operated vehicle (ROV) configuration. However, the specific requirements for water quality assessment necessitated the capability for the robot to execute vertical movements in precise increments, prompting the transition to an automated system.

This automation was facilitated by incorporating an additional pressure/depth sensor, enhancing the robot's precision in navigating to specific depths and locations within the water body. Automation was implemented using the Arduino IDE to control the motors. This involved programming a variable to represent the target depth and continually monitoring the current depth. The system is designed to activate the motors to adjust the robot's depth whenever the target depth exceeds the current depth, ensuring the robot can reach and maintain specified depths.

To sustain a particular depth for a set duration, the system persistently checks and adjusts the depth as necessary. Users have the flexibility to input their preferred depth and duration parameters directly into the Arduino program. Alternatively, manual control is available through remote controls (joysticks), allowing users to adjust the depth and navigate the robot vertically in fixed increments, such as one meter, providing both precision and user control in the robot's operation.

Data Collection and Analysis

The sensors used in our system are from Atlas Scientific. Data gathered include values in water pH, temperature, dissolved oxygen, conductivity, and oxidation-reduction potential (ORP). The data retrieval from the sensors is facilitated through two primary methods. The initial approach involves a direct connection between the sensor box and a laptop via a USB interface to the Arduino, enabling real-time data observation either through the Arduino's monitor or a bespoke web application. This setup is enhanced by integrating the sensors' output with an application known as CodeRed, which offers node functionality. This integration permits real-time data streaming and the visualization of live graphs.

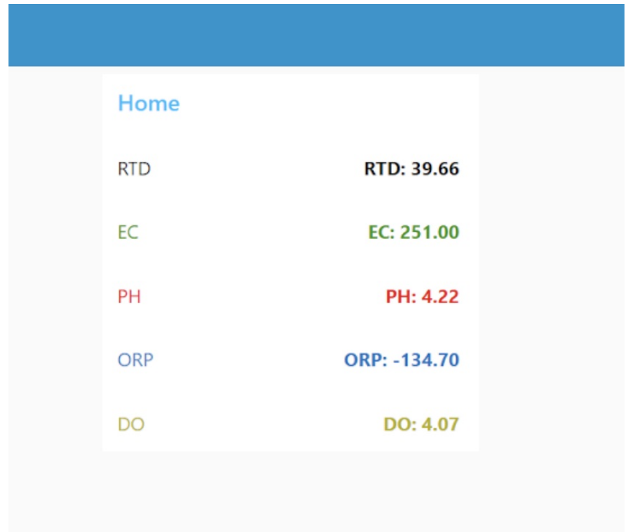

Figure 3: Web application for data reporting

Alternatively, data can be accessed via a microSD card, a method particularly advantageous in scenarios where laptop usage is impractical, such as remote or aquatic locations. To ensure compatibility with the Arduino microSD card module, the SD card must adhere to the FAT16 or FAT32 format. Unlike the live data collection method, this strategy records data onto the SD card for subsequent analysis with a compatible SD card reader.

Preliminary tests of water quality were conducted using samples from the Allegheny College pool, tap water, and soapy water, followed by initial testing at Pymatuning Lake. Data analysis was performed using a Python program that utilizes the Pandas, Numpy, and Matplotlib libraries. These libraries facilitated the cleaning and formatting of data, enabling the calculation of mean values for pH, oxidation-reduction potential (ORP), electrical conductivity, temperature, and dissolved oxygen.

Future Work

This spring, our team is undertaking extensive testing in local lakes, followed by the deployment of our system for water quality monitoring in collaboration with our local Conservation District throughout the summer.

Looking ahead, there are numerous opportunities for enhancing the project with additional functionalities. Incorporating advanced computer vision technology stands out as a significant improvement, enabling the detailed mapping of aquatic environments. Such capability would provide invaluable data for research endeavors, particularly in areas like erosion studies and the analysis of turbulent waters. Further enhancements in our water monitoring methodology also present a promising avenue for development. For instance, integrating sensors designed to identify algae blooms could greatly enhance our understanding of ecological imbalances.

References

Grattan, L. M.; Holobaugh, S.; and Morris Jr, J. G. 2016. Harmful algal blooms and public health. *Harmful algae* 57:2–8.

Moore, S.; Bohm, H.; Jensen, V.; and Johnston, N. 2010. Underwater robotics. *Science, Design and Fabrication. Marine Advanced Technology Education Center (MATE), Monterrey CA, USA*.

Paerl, H. W.; Havens, K. E.; Hall, N. S.; Otten, T. G.; Zhu, M.; Xu, H.; Zhu, G.; and Qin, B. 2019. Mitigating a global expansion of toxic cyanobacterial blooms: confounding effects and challenges posed by climate change. *Marine and Freshwater Research* 71(5):579–592.