Automatic Unmanned Surface Vehicle-Based Water Quality Monitoring Systems

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Introduction

Water is an extremely important natural resource. However, our water supply is at risk. Droughts and contaminants threaten our water supply. With less water available we must do all we can to protect what water we have. In an interview with the Water Agency Coordinator & Lead Chemist at Sonoma Water, Santa Rosa, California, the coordinator stated that most water testing is currently done with either stationary sensors at water intakes or manually through water samples. This limits the area that is tested and can make it difficult to have continuous testing over a wide area. This in turn can allow potential water contamination to go undetected. This can be solved by using a mobile platform to take a select few water quality measurements to allow authorities to gain a better understanding of water quality over a larger area [1]. The ability to take these measurements and record them for long-term water monitoring saves manpower and time [2].

Related Work

Most water quality monitoring systems such as the ones developed by the company In-Situ are stationary. While In-Situ has attempted an unmanned arial vehicle approach, it had issues such as drifting and landing on the water in a stable way.

Researchers at different universities from around the world have been involved in designing USVs for water quality management as well [3-7]. There were a variety of ways that they approached taking water quality measurements with a wide area. Some decided to take an autonomous approach rather than an automatic approach. However the issue with an autonomous USV is that it will not target specific areas of interest for measurement. An automatic USV that follows a planned path can take measurements in a methodical, strategic manner. Some of the USVs would also have a specific application where water quality measurement is secondary. For example in a USV developed by Chang the primary focus of their USV was to clean the water while it's secondary focus was to take pH readings of the water [8].

All of the USVs reviewed used the pH sensors while only two used dissolved oxygen and temperature sensors. A turbidity sensor is important as it shows the solid and particulate pollution. Temperature and Dissolved Oxygen are closely linked to the health of the body of water. With low dissolved oxygen or high temperature, the quality of water goes down. The pH sensor was selected because alkalinity is an important factor of water quality. Having just these few sensor measurements allows for a good general understanding of water quality.

USV Design

After extensive research, we decided to design a catamaran style USV versus a single-hull design due to its increased stability. The platform that sits between both pontoons allows a perfect place to mount the IPx4 rated box that will house all of the water-sensitive components. The propulsion of the USV will come from two thrusters that will be mounted on to two fins that extend past the pontoons and will be able to utilize differential steering to maintain its planned path. The overall proposed design of the USV is shown in the 3D rendering in Fig. 1.

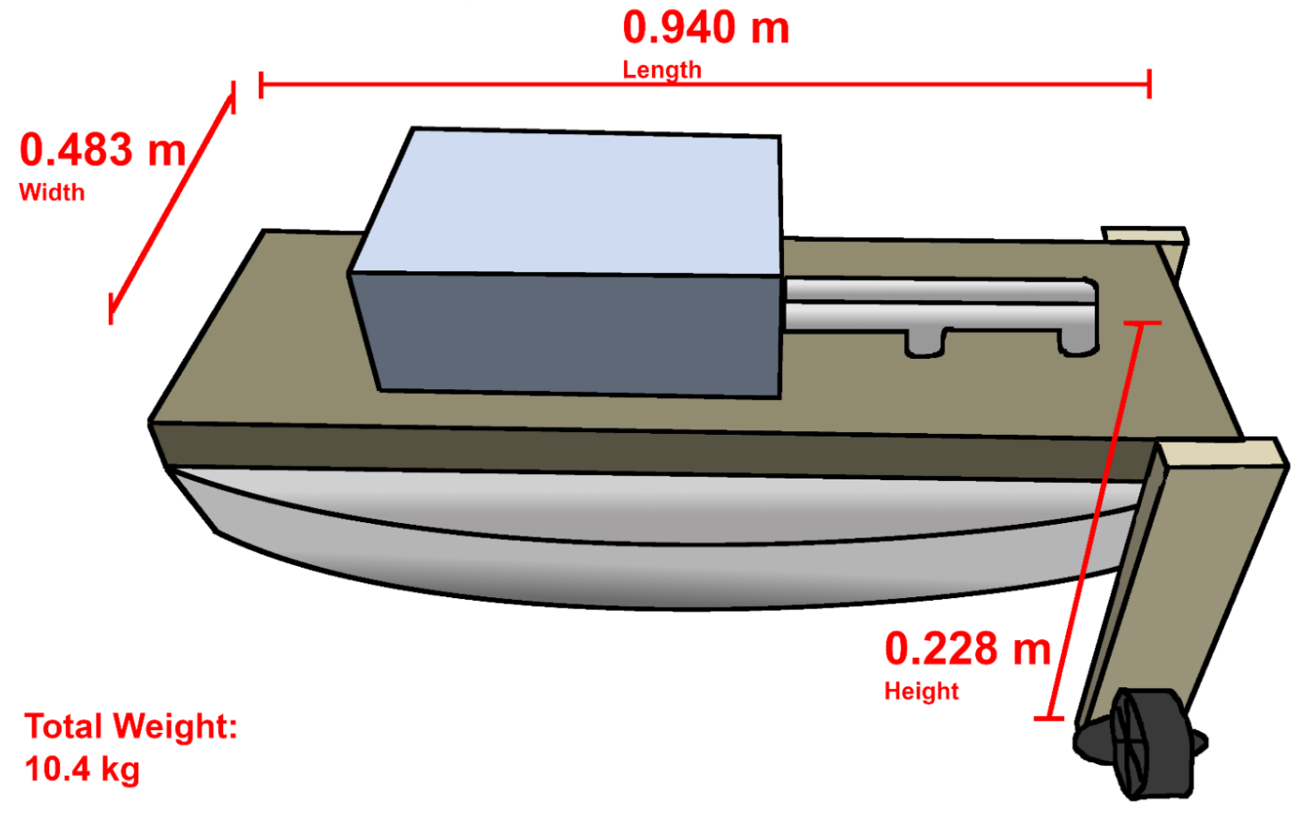

Fig. 1. 3D rendering of the USV prototype

Fig. 2 shows the system block diagram includes four main function modules-sensors, navigation, power, and base station. The base station can send the planned path to the flight controller in the navigation module. The flight controller will communicate with the GPS, indicating its location, as well as the motors to reach designated waypoints. At these waypoints shown in Fig. 3, the flight controller will issue a command to the microcontroller in the sensor module. The sensor module is where our microprocessor and our four sensors turbidity, pH, dissolved oxygen, and temperature reside. Once the sensors are initiated at the designated waypoint, the sensor data is gathered and sent to onboard data storage.

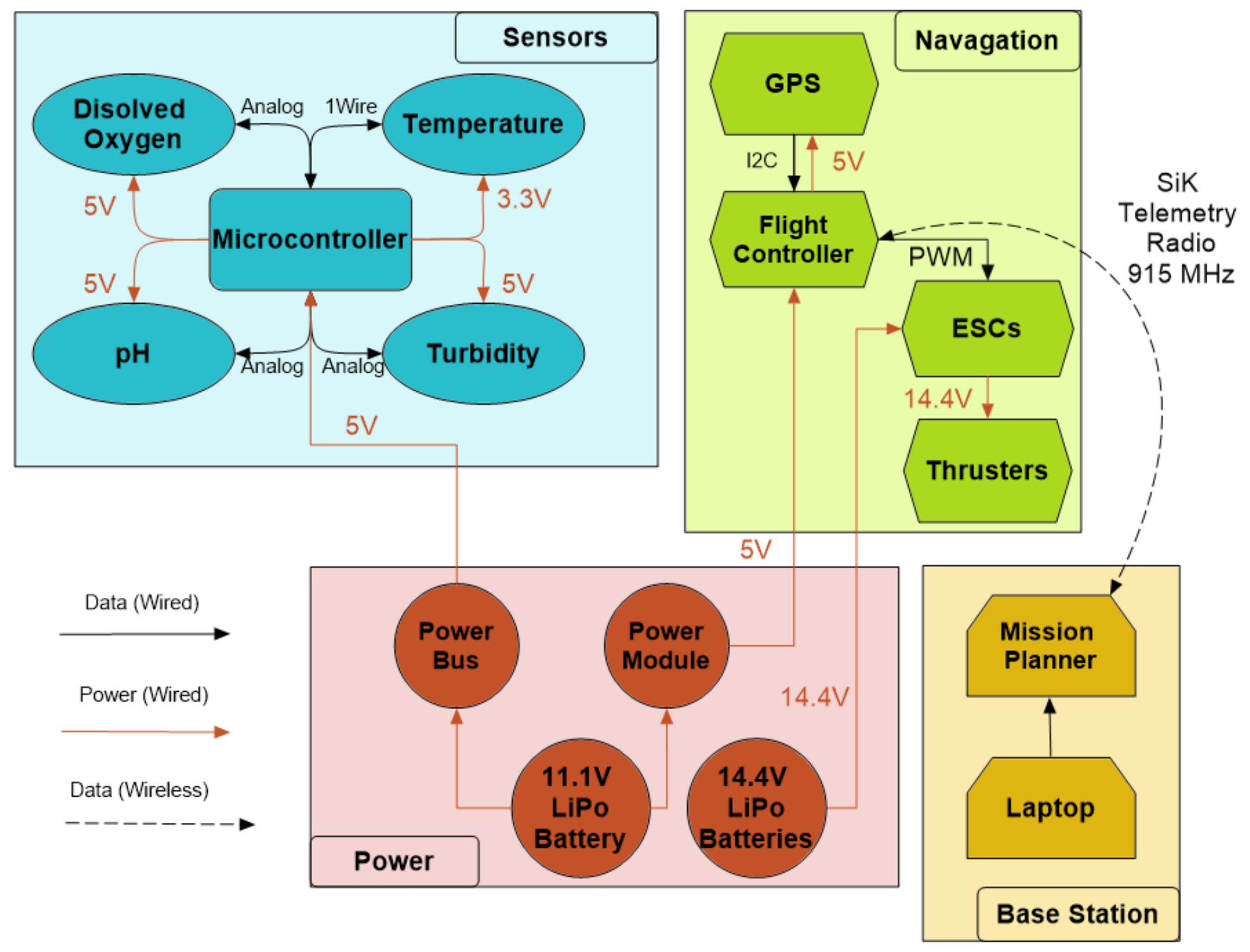

Fig. 2. System Block Diagram Proposed USV

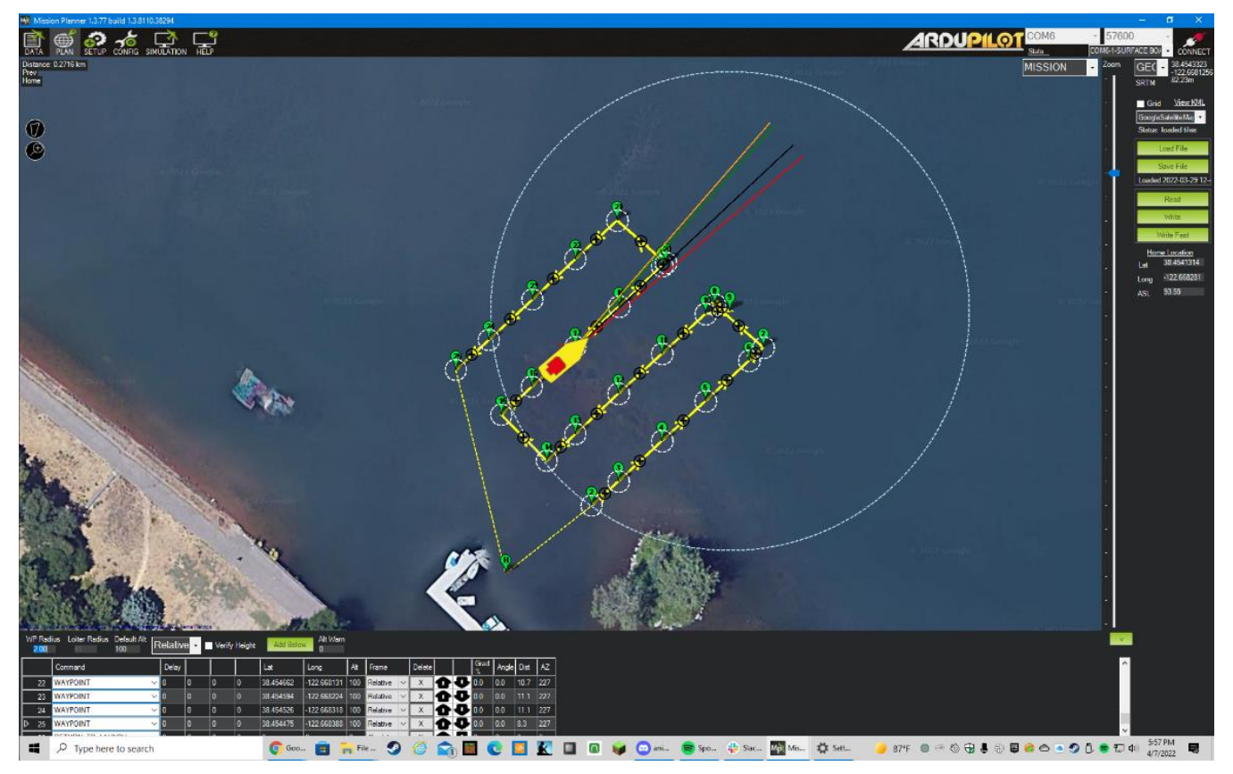

Fig. 3. Autopilot Planned Path

Experiment Results

The USV is able to navigate a pre-planned path automatically as seen in Fig. 3. The USV is able to follow it's planned path with an average accuracy within 1.834 meters according to data obtained from testing in lakes, shown in Fig. 4. Parameters such as speed and acceleration can be altered easily by the user in the flight planning software depending on how stable they wish the USV to be, or how quickly they need the path to be completed.

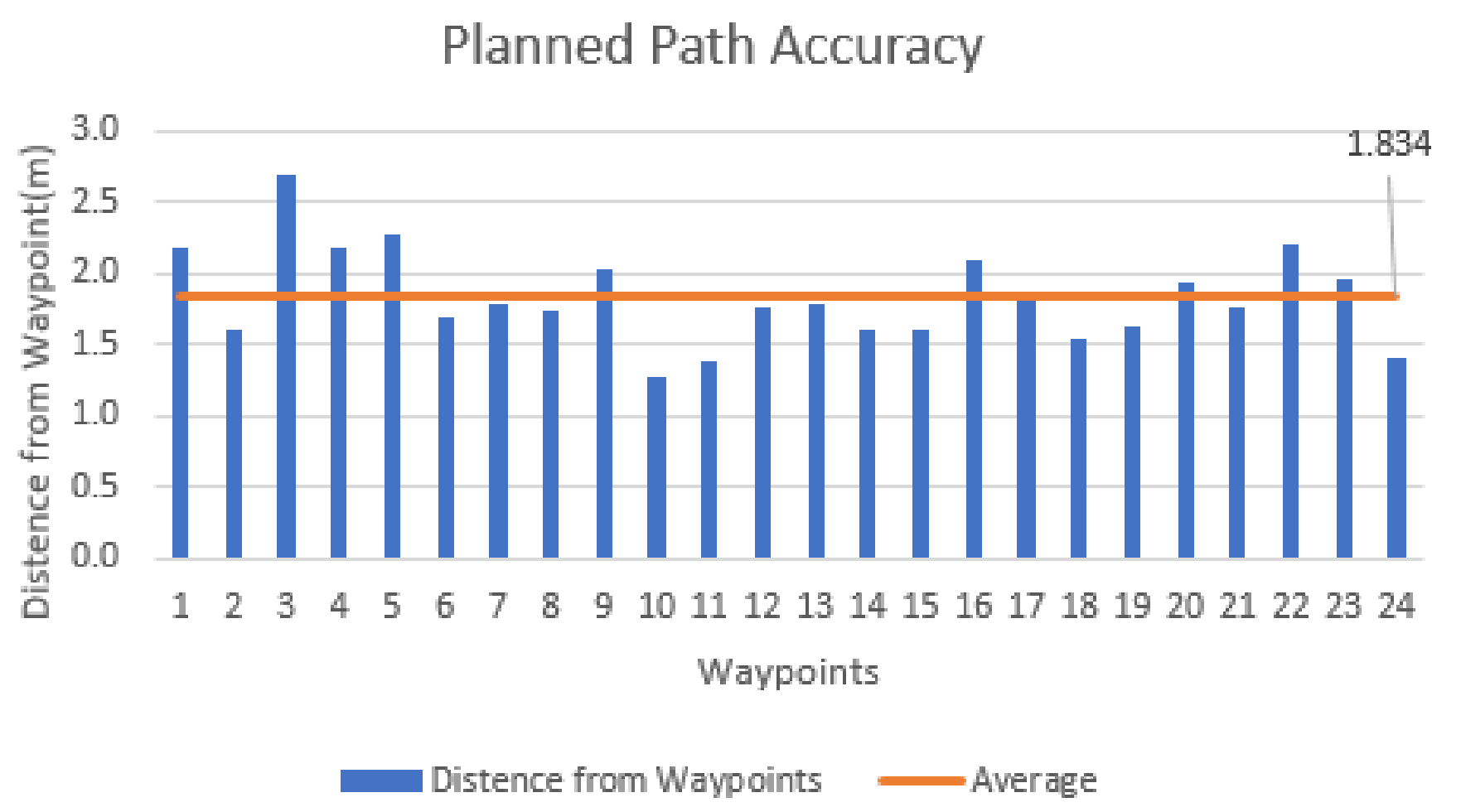

Fig. 4. Planned Path Accuracy graph

The water quality sensors have been tested and integrated into a single microcontroller on the USV and are able to take readings. The accuracy of the pH sensor is +/- 0.19 pH, the temperature sensor is +/- 0.7 degrees Celsius, and the turbidity sensor +/- 28.8 NTU below 25 NTU and +/- 5.6% above 25 NTU.

The USV and sensor module has preformed real-world tests in lakes. The readings recorded from the temperature and turbidity sensors appear to correspond with what was expect. The turbidity sensor is fairly inaccurate. The pH sensor appears to have difficulty talking measurements while in motion and the temperature sensor preformed excellently. These readings can be seen in Figs. 5, 6, and 7.

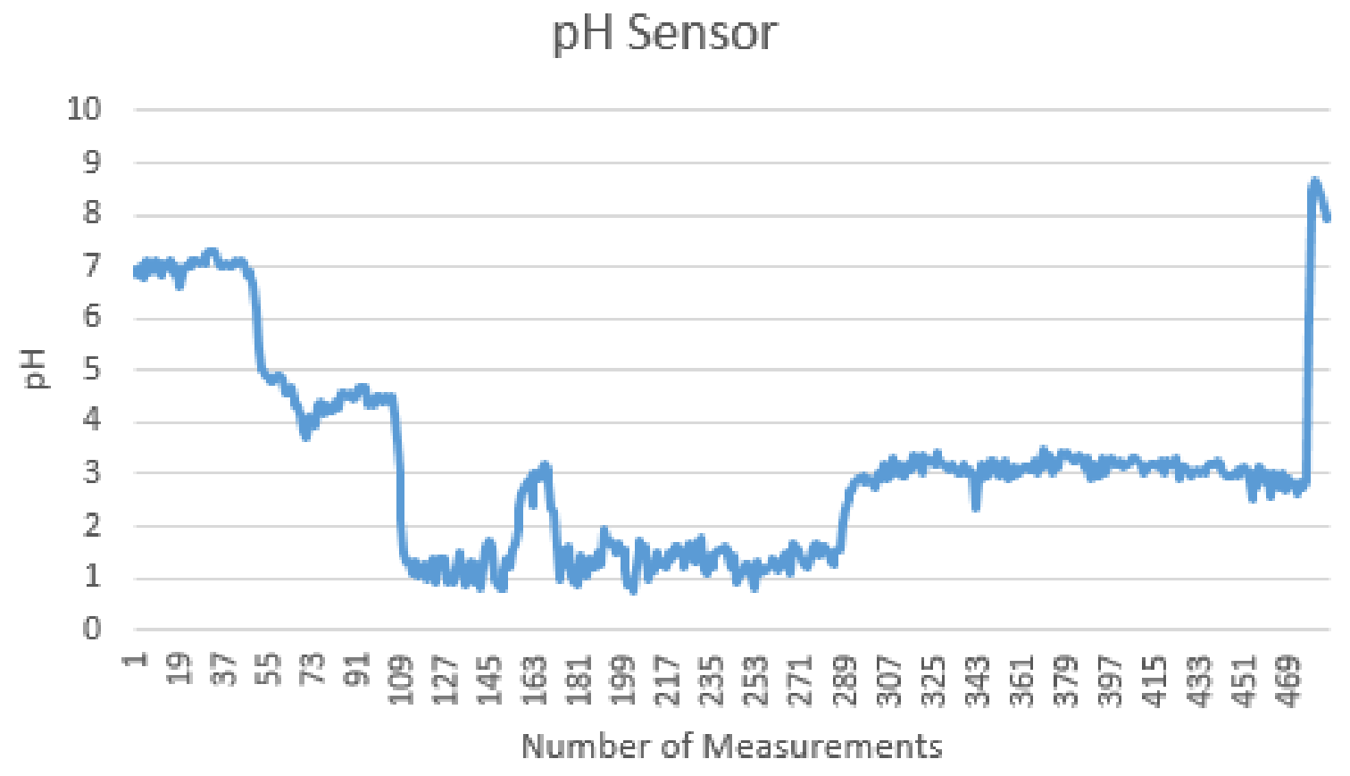

Fig. 5. pH Sensor

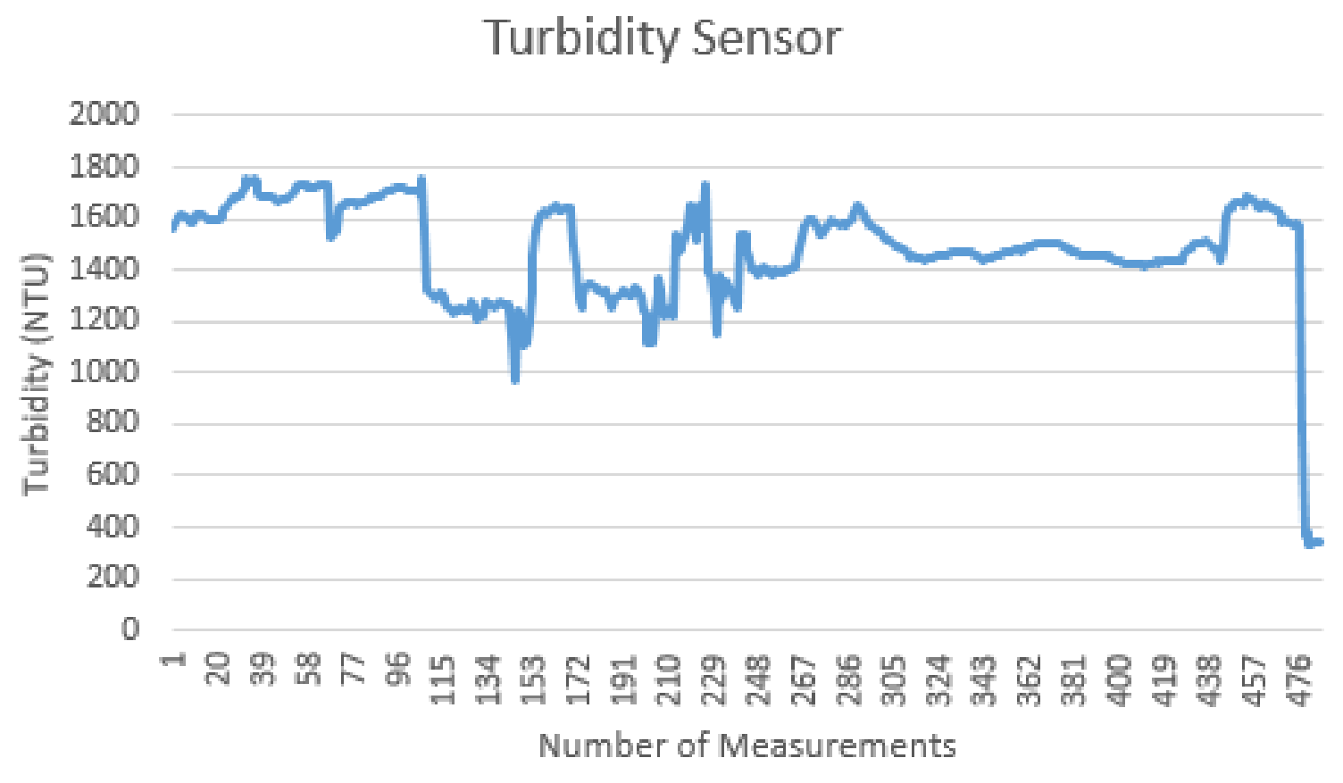

Fig. 6. Turbidity Sensor

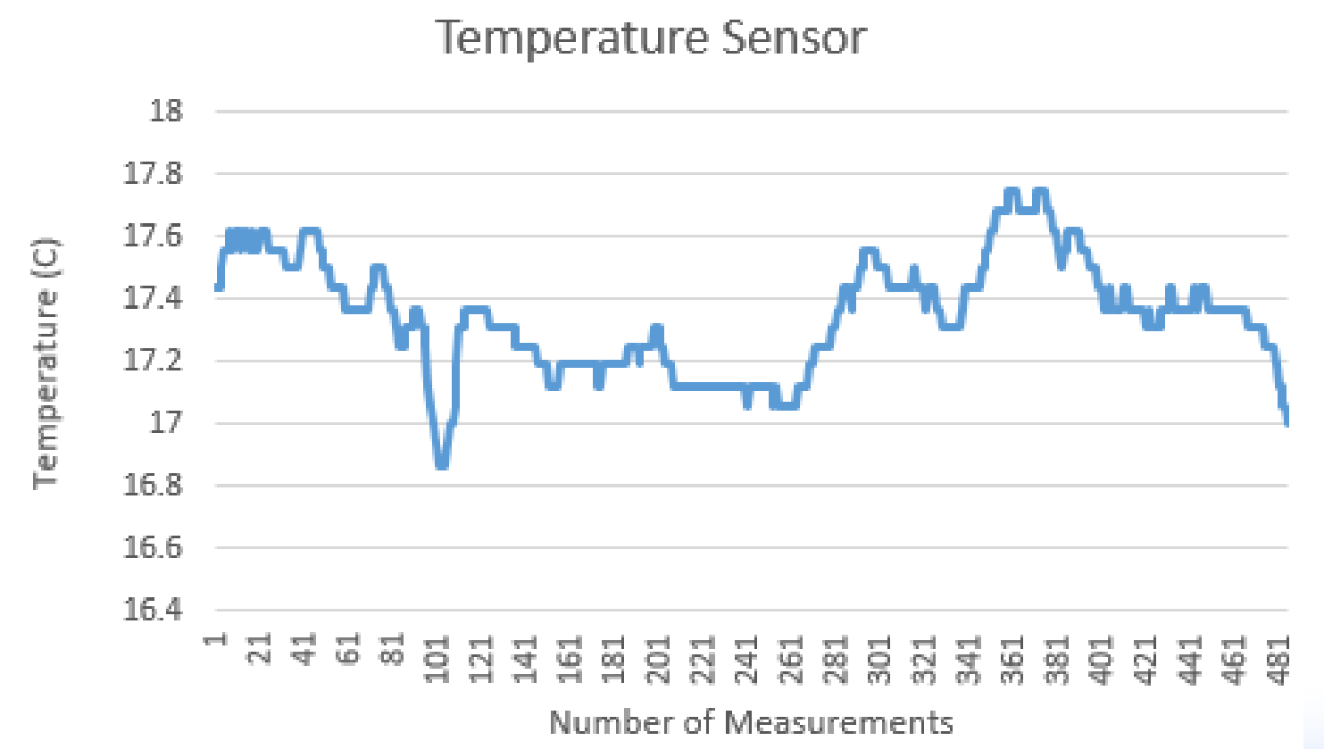

Fig. 7. Temperature Sensor

Thrusters have been tested for power consumption. At 50% throttle each thruster consumes an average of 500mA of current. After performing basic calculation with a known battery capacity, we have determined that the thrusters can operate for a maximum of 2.48 hours at 50% throttle. This calculation is based off a discharge rate of 80% for the LiPo battery. Fig. 8 shows our USV travelling a planned path for data colletion.

Fig. 8. USV Travelling Planned Path for data collection

Conclusion

Water is a vital resource for all living organisms and our water sources are under threat. Current monitoring systems used to test water quality are limited by time, manpower, and area coverage. Our review of other unmanned surface vehicles has found that many of them suffer from different and similar issues. The selected sensors take into account major aspects of water quality that allow for a general grasp of water quality. The flight controller and navigation system were selected for automation and accuracy. These components are all brought together into a USV, based on a catamaran design chosen for its stability. This creates a stable, accurate, reliable, and mobile solution to water quality monitoring.

Future Work

Improvements to our current design can be made on data transfer from the USV in real-time data analysis. It is also nice to add collision avoidance to ensure that the USV is able to complete it's planned path without interruption. The sensor reading can be improved to meet higher accuracy requirement.

Acknowledgements

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