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Capstone project progress on the floating buoy IoT device development for mosquito research

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Session XXXX

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Abstract

Mosquitoes may transmit diseases and viruses such as malaria, dengue, and the Zika virus that can lead to disabling and potentially death. Mosquitoes tend to lay their eggs in standing bodies of water. By knowing what type of standing water mosquitoes are typically found in, we can conduct research on their habitat. For mosquito research, environmental and water property data can be used in studying the effects on the breeding sites of mosquitoes. In order to understand their breeding patterns and habitats, there is a need to create a floating buoy IoT (Internet of Things) device. It is a form of a buoy that can measure and monitor water properties of a standing body of water. The collected data can assist in the mosquito population control to save lives. For the development of this IoT device, a capstone project was created in the Fall of 2021. The task for this capstone team is to create a remotely operated floating buoy which can collect environmental and water property data from standing bodies of water. This project can allow students to help in having an experiential learning and potentially serving a general population through the further research and study about mosquito breeding pattern. In this paper, the ongoing progress of this capstone project for mosquito research is introduced.

Introduction

Mosquitoes are known to be dangerous, and they are able to transmit diseases and viruses such as malaria, dengue, and the Zika virus. It could be fatal, potentially even a death. Mosquitoes could lay their eggs in stagnant water. By knowing the properties of standing water where mosquitoes may lay eggs, we could make further progress on research of their habitat. In this aspect, for mosquito research, environmental and some of the water property data can be measured for research and study for the effects on the breeding sites of mosquitoes.

In order to understand their breeding patterns and habitats, there is a need to create a floating buoy IoT (Internet of Things) device. It is a form of a floating buoy that can measure and monitor water properties of a standing body of water. The collected data may assist in the mosquito population control to save lives.

For the development of this IoT device, a capstone project was created in the Fall of 2021. A capstone project in the Electronic Systems Engineering Technology Program at Texas A&M

University is a two-semester project. This capstone team consists of four senior Engineering Technology (ET) students. An ET faculty member has been advising this project. The task for this capstone team is to create a remotely operated buoy which will collect environmental and water property data from standing bodies of water. The remotely operated buoy can store the data locally, send the data to a base station, and into the cloud for further analysis. The buoy will consist of thrusters and a GPS (Global Positioning System) module to ensure the device stays in a certain radius of a target location.

This buoy can collect data from water temperature, pH and pressure sensors. The buoy can also collect environmental data such as ambient temperature and wind speed. In this buoy, a Beaglebone® Black Wireless platform is used as a controller. This project can allow ET students to help in having an experiential learning and potentially to serve a general population through the further research about mosquito breeding pattern. In this paper, the ongoing progress of this buoy capstone project for mosquito research is introduced.

Capstone project management under the impact of COVID-19

Engineering Technology students can learn a great amount of knowledge and solidify their learning through their capstone projects. These capstone projects offer students to learn through experiential learning. There have been many challenges due to the COVID-19 [1][2]. Educators and instructors have been adapted to continue to provide valuable experiences for students [3][4].

For the Spring semester 2021, the authors' institution, Texas A&M University, has been continuing providing classes and education to the students via a mixed mode of in-person and remote classes. In Fall 2021, Texas A&M University had operated in-person classes at full capacity [5]. In the following Spring 2022, Texas A&M University has been operating to continue to provide in-person classes. These mode changes of operation have impacted the capstone management of the team in this paper.

This capstone project started in Fall 2021, capstone meetings with the faculty advisor were able to be managed as back-in-person meetings instead of on-line Zoom meetings in Fall 2021. Authors have experienced that there have been more engaging discussions and conversations during the meetings. However, there have been unexpected challenges on the electronics side. There is a global chip and electronics shortage. This issue has been a challenge in designing and implementing the prototype device. Authors have been trying to adapt to the situation. For instance, a Raspberry Pi board was considered as a main processing unit for this project. Since there was a shortage of the Raspberry Pi boards back in 2021, the team had switched it to a Beaglebone® Black Wireless board instead. As of February 2022, the COVID-19 and electronics shortage situations have not yet been completely resolved. Using these alternative part choices, this project is currently manageable, and it is expected to be completed successfully by the end of the Spring 2022.

For this capstone team, four students have been working on this project, and the goal of the project is to build a floating buoy that can perform water property testing for mosquito research. The purpose behind this device is to aid mosquito research. It is expected to use this device to help further understand the spread of vector-borne diseases.

Floating buoy IoT device development for mosquito research

For mosquito research, there can be a need of monitoring and collecting water properties of a potential breeding spot. In this capstone project, this new device is under development. This can be conducted by the aid of the device that can capture environmental and water property data while remaining in one area in the standing bodies of water. This device is similar to a remotely operated buoy which can collect environmental and water property data. This buoy device includes sensors that can measure pH level, water pressure and water temperature as well as the ambient temperature and wind speed. This device can collect the data during the given amount of time interval, and it can be remotely operated. This buoy device can upload the data to the base station and into the cloud for later data analysis. Moreover, this buoy device has a GPS module, and thrusters and propellers, which can control the location of the device. This floating can be automatically operated to be within a predefined location, or this device can be manipulated remotely using a controller at the base station.

Concept of Operation

This floating buoy system consists of two devices: the buoy and base station. This system is designed to be portable to ensure the researchers and scientists can carry them to a body of water being tested. This buoy will be placed in the water, and the base station can control the buoy remotely on the ground. A controller is used, and it can manipulate the location of the buoy. This location can be read via a GPS module. The buoy can collect the data at the predefined location. If it would drift outside of a certain radius from this location, the buoy can attempt to fix its location to station at this predefined location.

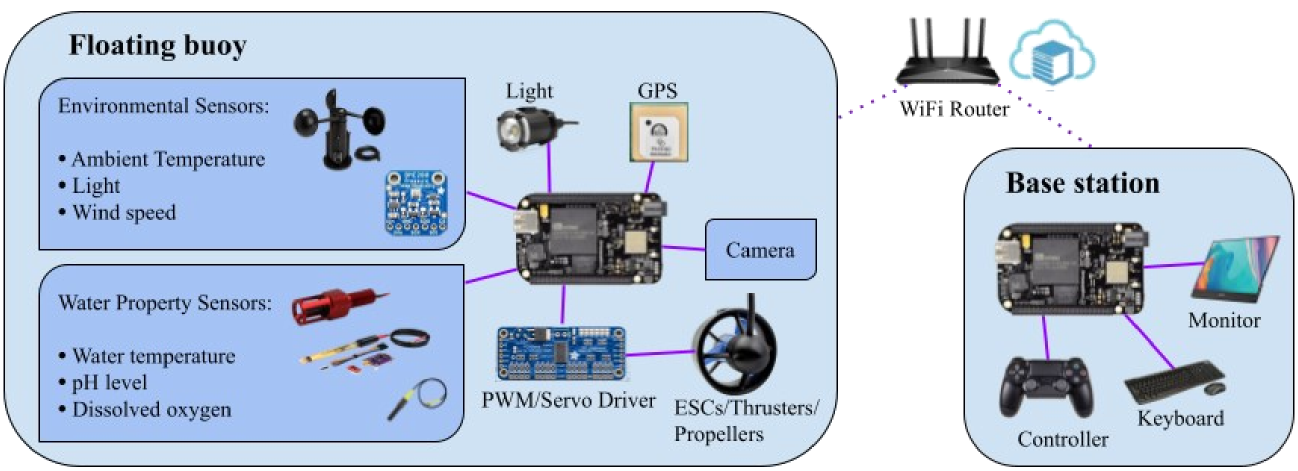

Figure 1. Conceptual block diagram of the floating buoy and Base station

The buoy can be operated autonomously as it can collect the environmental data, video feed, and GPS location. The environmental data will consist of the wind speed, ambient temperature, pH level of the water, dissolved oxygen, light intensity, and temperature of the water. The camera will be used to show the base station video feed as well as capture images periodically under the water with the assistance of a light. The images and environmental data will be sent automatically to a router that will share this data with the base station and a cloud when internet access is available. Figure 1 shows the conceptual block diagram of this floating buoy system.

The system consists of two main subsystems, the buoy and base station. They work together to collect and transfer the data. The buoy includes a Beaglebone Black Wireless, various sensors such as an anemometer, ambient temperature sensor, dissolved oxygen sensor, pH level sensor, camera, light source, GPS and other peripheral devices such as a PWM (Pulse Width Modulation) servo driver, and thrusters. All of these components will be stored inside of the buoy except for the anemometer and thrusters due to their function.

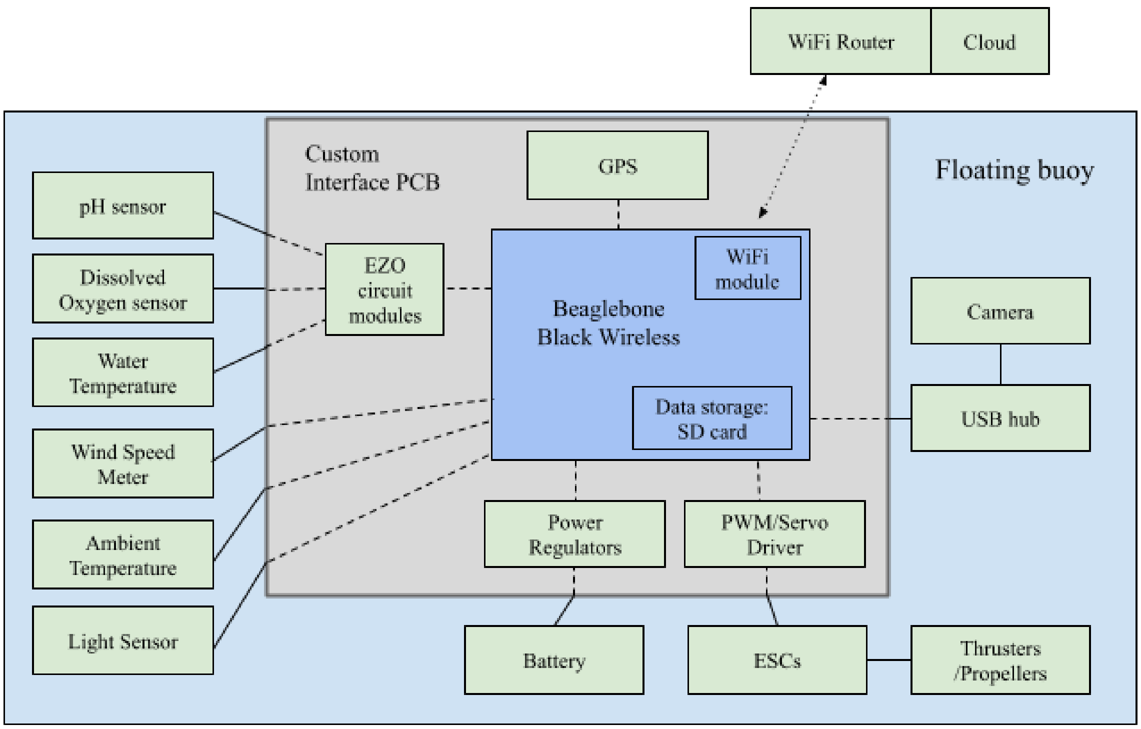

Figure 2. Functional block diagram of the floating buoy device.

The Beaglebone Black Wireless board is used to read and collect the data sent by the sensors, camera, and GPS. A light source is needed for the operation of the camera in a dark environment. Using the built-in wireless communication module, the Beaglebone Black can send the data collected to a router that can later be sent to the cloud and the base station. Lastly, the data collected by the GPS will be used to calculate if it needs to relocate by providing directions to the PWM servo driver and to navigate the buoy to its target location.

The functional block diagram of the floating buoy sub-system is shown in Figure 2. The data type of the sensors is mostly digital except the wind speed meter. The sensor data for the pH, dissolved oxygen, and water temperature is processed by the EZO modules, and the data will be sent to the Beaglebone Black wireless. The processed data by the Beaglebone Black wireless can be transmitted to the WiFi router at a predefined interval. The router will then transfer the data to a cloud to be later observed as well as to the base station. The base station includes another Beaglebone Black wireless board with a monitor and keyboard. The video and image data can be recorded locally in micro-SD card of the buoy, and the selected data can be transferred to the Beaglebone Black wireless in the base station

Hardware design

The main purpose of this floating buoy system is to measure water and ambient properties. The device includes ambient and water temperature sensors, water pressure sensor, anemometers, pH sensor and a GPS module to track its location. These sensors are connected via I^2C (Inter-Integrated Circuit) or UART (Universal Asynchronous Receiver-Transmitter) serial communication peripherals to the Beaglebone Black wireless. The custom interface PCB that was previously shown in Figure 2 makes the system work together. The alpha schematics of this interface board is shown in Figure 3.

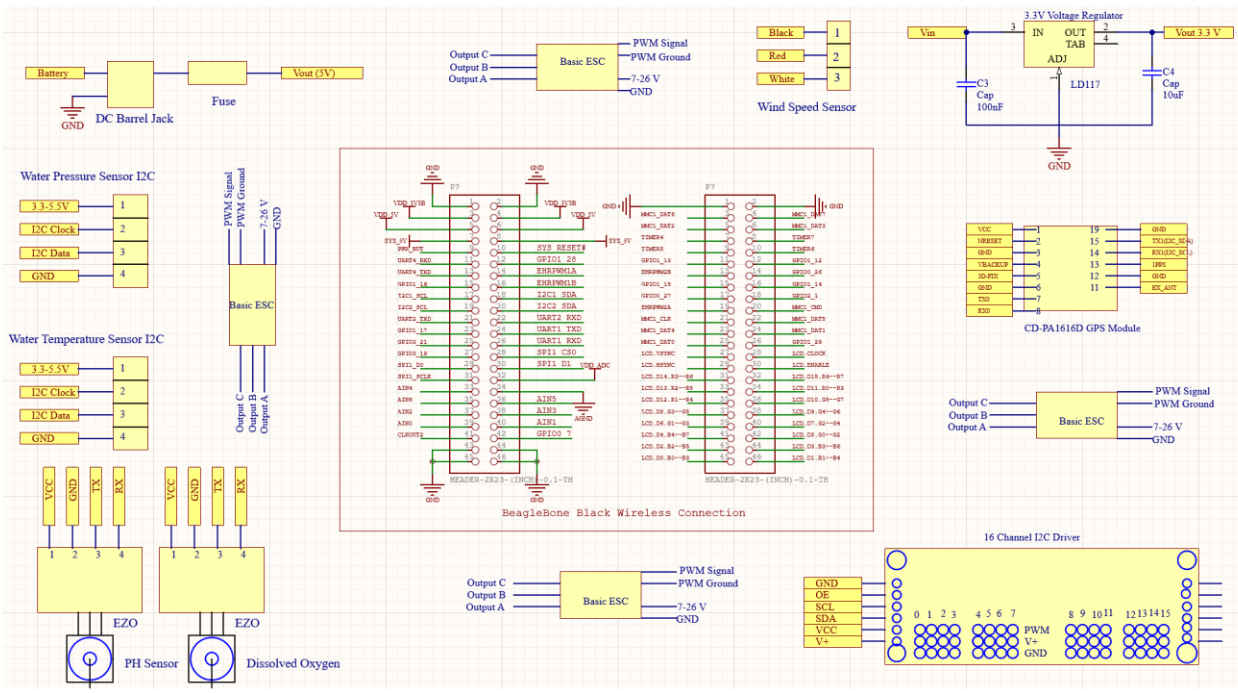

Figure 3. Alpha schematics of the interface PCB.

This PCB includes a voltage regulator to provide power to sensors. Also, it includes connections to the ESC (Electric Speed Controller) modules, and connectors for sensors. This interface board will be located inside an electronics enclosure to prevent water damage. However, some of the sensors will be located outside of the electronics enclosure. For instance, the ambient temperature sensor and water property sensors will be installed outside of the electronics enclosure connected via wires to the custom interface PCB.

Software design

The software consists of the main program to control the operations and the sub-programs for sensors. The main operation is to process it to control the buoy by a user to station at a desired location. This location is then set as the designated GPS location. This is where the buoy will take environmental and water property data from. The purpose of the device is to take data from mainly the defined GPS location. However, due to the wind, currents/waves, and other environmental factors, the buoy is prone to drifting away from the GPS location. To fix this issue, a program will be run to check the location of the buoy periodically. It then gathers data using its sensor and collects video footage that will be transmitted to the router and base station. It will then cycle back to checking its location until the user has decided they do not want to keep taking data. The user will then manipulate the controller to navigate the buoy to the shore to be able to retrieve the buoy out of the water.

Mechanical design

The mechanical drawing and the picture that is in construction is shown in Figure 4. On the left side, it shows the 3D model of the buoy. The frame consists of the aluminum extrusions. The base frame has been raised to place water sensors underneath. The wind sensor is located at the top of the frame. Two thrusters are placed on the buoy. They can allow the floating buoy to adjust its position on the water. On the right side, it shows the picture of the buoy in construction. The electronics enclosure has not been installed yet. This electronics enclosure that will be placed in the center is waterproof, and it can contain the electronics parts. The sensors and GPS antennas will be installed outside of the electronics enclosure.

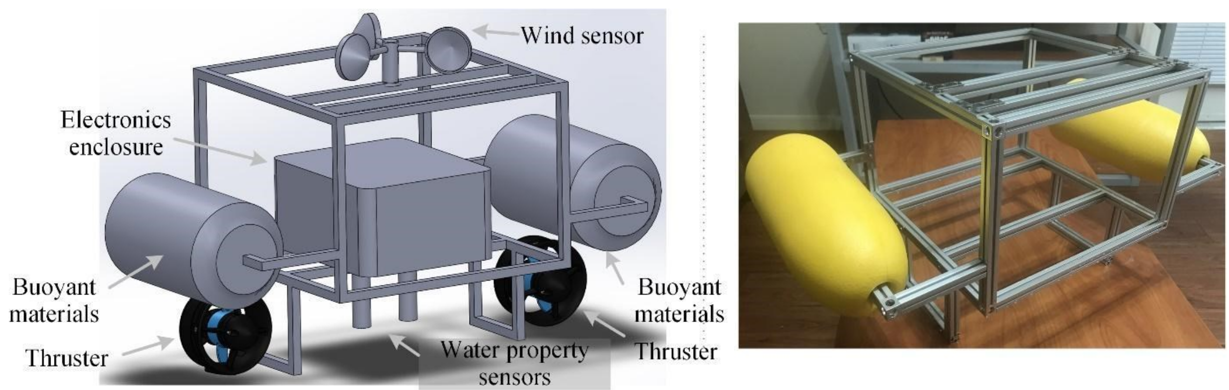

Figure 4. Mechanical drawing and the construction in process.

Project management

This project is organized to be conducted for two semesters. The first semester of this capstone project is Fall 2021 and the second semester is Spring 2022. In the earlier portion of the first semester, the team members spent time creating this idea and the plan for the project. Next, the detailed analysis was followed to break down the tasks, and the work breakdown structure was created. The tasks were assigned to students, and the Gantt chart was created. As an example, the Gantt chart for Fall 2021 is shown in Figure 5. There are four sections in the Gantt chart. They are hardware, software, integration, and documentation. This Gantt chart shows integration and documentation sections. The Gannt chart allows students to see the tasks that need to be completed and the specific deadlines. This chart helps students know which tasks will take longer and which will be much shorter to complete. The chart is color coded to adequately show the tasks of each student in the project.

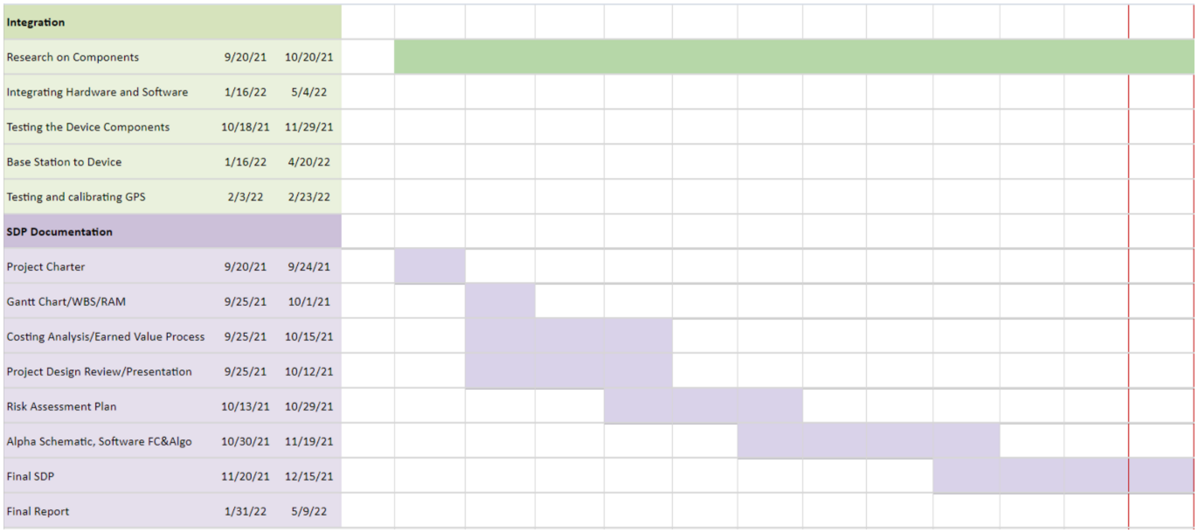

Figure 5. Gantt Chart (Integration and documentation sections) for Fall 2021

Educational value and Observation

This capstone project has been used as a tool to educate engineering students about the engineering skills as well as the science and public health related to vector-borne diseases. Moreover, students have been learning about the water properties. Typically, these are not the scope taught in an engineering technology curriculum. Students have been expanding their horizon in learning many skills and obtaining knowledge for this project.

Based on the student's statements, students have learned the importance of teamwork and planning as well as the division of the tasks. And, some of them stated that it could serve as a valuable experience for their future jobs and this experience would introduce how the projects in the professional world would be. The list of the specific skills and tools that the students learned are SolidWorks®, Altium Designer®, Linux O/S (Operating System), and Python programming. Students are preparing the design review and the buoy system is in testing and in integration.

After the successful completion of building this prototype and capstone project, the field testing and measurements are planned to be performed and it may expand its value and impact to the general public and scientists in other fields of study.

Summary and Conclusions

The prototype of this floating buoy system will provide a method to analyze environmental and water property data of stagnant water for mosquito research. This prototype device includes an anemometer, ambient temperature sensor, and a light sensor to collect environmental data. The device also includes pH probe, dissolved oxygen probe, temperature sensor, and a pressure sensor to collect water property data. This system can make the buoy stay around in the water up to a certain radius. When the buoy stays outside a certain radius, thrusters would be activated and move the device back to within the radius. The environmental data and water property data collected from the device can be used for mosquito research. This capstone project started in Fall 2021, and it is expected to be concluded in Spring 2022. Despite the chip and electronics shortage issues related to COVID-19, students have been obtaining various engineering skills through experiential learning, and they have been expanding their horizons to apply their engineering skills for this scientific instrumentation development.

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