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# Development of Mosquito Breeding Environment Testing Instrumentation via Capstone Project

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## Abstract

Mosquito larvae can be found in stagnant water in abandoned or discarded tires. The impact of the microclimate environment and the water properties in these tires may be monitored for an extended period of time. In order to assist the research on this aspect, a mosquito breeding environment testing instrumentation was created by a capstone project team. The capstone project was started in Spring 2022 and concluded in Fall 2022. Five undergraduate engineering technology students have conducted this capstone project, and an engineering faculty member advised this capstone project. This prototype of a mosquito breeding environment testing instrumentation has a testing chamber that can contain tires partially filled with water inside, and a sliding light source to emulate the light condition variations. The testing instrumentation has sensors to obtain data such as ambient temperature, humidity, CO2, and light intensity. In addition, the testing instrumentation can measure water properties such as water temperature and pH, and it can send the data over the internet. A user can also control the sliding light source over the internet. A GUI program using the .NET framework can access data and control the instrumentation. The images can be stored on a local microSD card. For the main controller, a BeagleBone Black board was used, and the sliding platform was implemented using a stepper motor. In this paper, the details of the mosquito breeding environment testing instrumentation and the educational lessons learned via this engineering capstone project are presented.


## I. Introduction

Mosquito larvae can be found in stagnant water in abandoned or discarded tires [1-3]. Abandoned tires left outdoors can collect stagnant water from the rain. These types of environments could be a potential environment for mosquitoes to breed. The impact of the microclimate environment and the water properties in these tires may need to be monitored for an extended period of time. However, it can be challenging to find, keep, and manage the tires in a natural environment for a long period of time. To obtain the data, researchers would need to visit the test site regularly at risk of infection during the data collection process.

For this reason, to assist this research, a mosquito breeding environment testing instrumentation was created to mimic the environment of abandoned tires. This prototype of the mosquito breeding environment testing instrumentation has a testing chamber that can contain tires partially filled with water inside and a sliding light source. The testing instrumentation has sensors to obtain data such as ambient temperature, humidity, $CO_2$, and light intensity. In addition, the testing instrumentation can measure water properties such as water temperature and pH, and it has the capability to send data and be controlled remotely through the internet. A user can also control the sliding light source over the internet.

This project was carried out by an undergraduate capstone project, and the capstone project was started in Spring 2022 and concluded in Fall 2022. Five undergraduate engineering technology students formed a team for this capstone project. They were advised by the first author. The details of the mosquito breeding environment testing Instrumentation development via a capstone project are presented in this paper.

## II. Capstone project management

A capstone project is related to experiential learning, and the students learn how to solve a real-world problem in a project-based learning environment [4][5]. Through this process, students could obtain an in-depth understanding of their field. For the capstone project in this paper, five students worked together for the common goal of the completion of the given project. They take on different roles in the team. In this project, the roles include Project Manager, Hardware Engineer, Software Engineer, Mechanical Engineer, and Test Engineer.

This capstone project team shows interesting diversity and inclusion. Three out of five students of this capstone project are male engineering students and two of them are female engineering students. The majority of them are related to Hispanic students. Texas A&M University at College Station is a Hispanic-serving institution. For the ethnicity breakdown of the Texas A&M University at College Station, white students are 57.0%, Hispanic students are 25.0%, Asian students are 10.4%, and black students are 2.8% in Fall 2021 [6]. For the ethnicity breakdown of the first author's Department of Engineering Technology and Industrial Distribution (ETID), the total of white students is 54.3%, the total of Hispanic students is 28.5% and the total of black students is 3.3% in Fall 2021. In this capstone team, the percentage of Hispanic students is higher than the Department average. For the gender breakdown of the ETID department, the total of male students is 84.0% and the total number of female students is 16.0%. In this capstone team, two out of five students were female engineering students, and the percentage of female students is higher than the Department average.

A few of the students in this team showed interest in working for a capstone project that I advise after taking my ESET 369 embedded systems course. Later, more members were added to the team, and it became this five-team member capstone project. For reference, the typical number of the capstone team in ESET (Electronic Systems Engineering Technology) program is four in the year of 2022. This capstone project was created in Spring 2022, and it was concluded in Fall 2022. During the summer semester, there was no official capstone activity. For Texas A&M University at College Station, the mode of operation was already back to the mode of in-person learning. The team had regular weekly in-person meetings with the faculty member. The name of this capstone project team was Mosqui-Tech. Although this capstone project was concluded in Fall 2022, further development and testing are planned to be continued.

## III. Mosquito Breeding Environment Testing Instrumentation

A conceptual block diagram of the mosquito breeding environment testing instrumentation is shown in Figure 1. The instrumentation includes a sturdy enclosure and a tire is placed inside of the enclosure. Within this enclosure, various sensors are installed. The sensors include ambient temperature, Humidity, $CO_2$, and Light Intensity as well as Water temperature and pH level of the stagnant water inside of the tire. The measured sensor data can be transmitted to a cloud service via the internet. A user can access the data via the internet. For the cloud service in this project, Microsoft Azure cloud service is used [7][8].

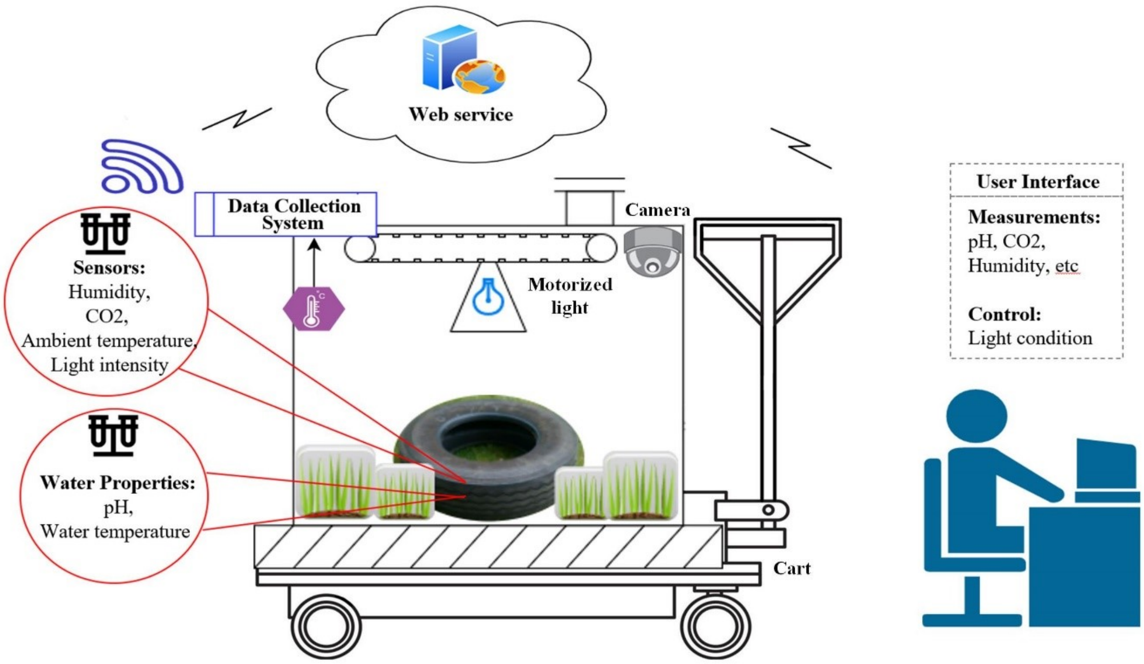


**Figure 1. Conceptual Block Diagram of the testing instrumentation**

The user can also control the motorized light remotely via the internet. Motorized light can create different light conditions. A camera is installed and controlled to store images inside the testing chamber at a defined interval. For the main controller of this instrumentation, a BeagleBone Black board is used [9-11]. A Debian Linux operating system can be installed on this board. The main program for the instrumentation can be written using Python Language.

## A. Hardware design

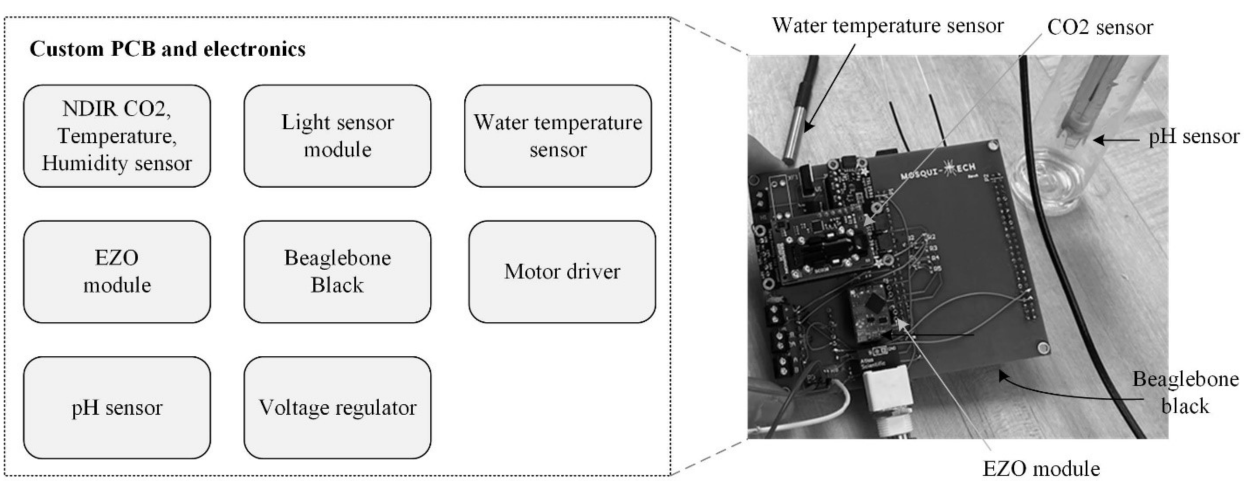


**Figure 2. Electronic system (Block diagram on the left and the picture on the right)**

The electronic system is shown in Figure 2. The block diagram on the left shows the custom PCB ad electronics and the picture on the right shows the assembled controller electronics. The custom PCB was designed to be used with the BeagleBone Black board. As shown on the left side, the custom PCB board includes the NDIR (Nondispersive infrared) $CO_2$ sensor, ambient temperature sensor, and humidity sensor. The Adafruit SCD-30 sensor includes these sensing components [12]. Moreover, the custom PCB includes sensors to measure water temperatures and pH levels. Furthermore, the custom PCB includes a stepper motor controller to control the horizontal position of the light.

On the right side of Figure 2, it shows a picture of the assembled electronics. The BeagleBone Black board is installed on the back of the custom PCB. The data from the Atlas Scientific pH sensor is properly processed by the EZO sensor [13-15]. The BeagleBone Black board can read the data from the EZO sensor via $I^2C$. For the water temperature sensor, a sensor based on a DS18B20 IC is used [16]. To measure the light intensity, a TSL2591 module is used [17], and the sensor data can be accessed over $I^2C$.

## B. Mechanical Design

Mechanical system is shown in Figure 3. The picture of the mosquito breeding environment testing Instrumentation is shown on the left side. A tire is placed inside, which can be found in the bottom of Figure 3. The assembled electronic board is placed inside of an electronics housing. A motorized light is installed on the top of the test chamber. Another picture is taken for the motorized light and shown on the top right of Figure 3. The light can be controlled to slide horizontally. In addition, the angle of the light can be adjusted manually.

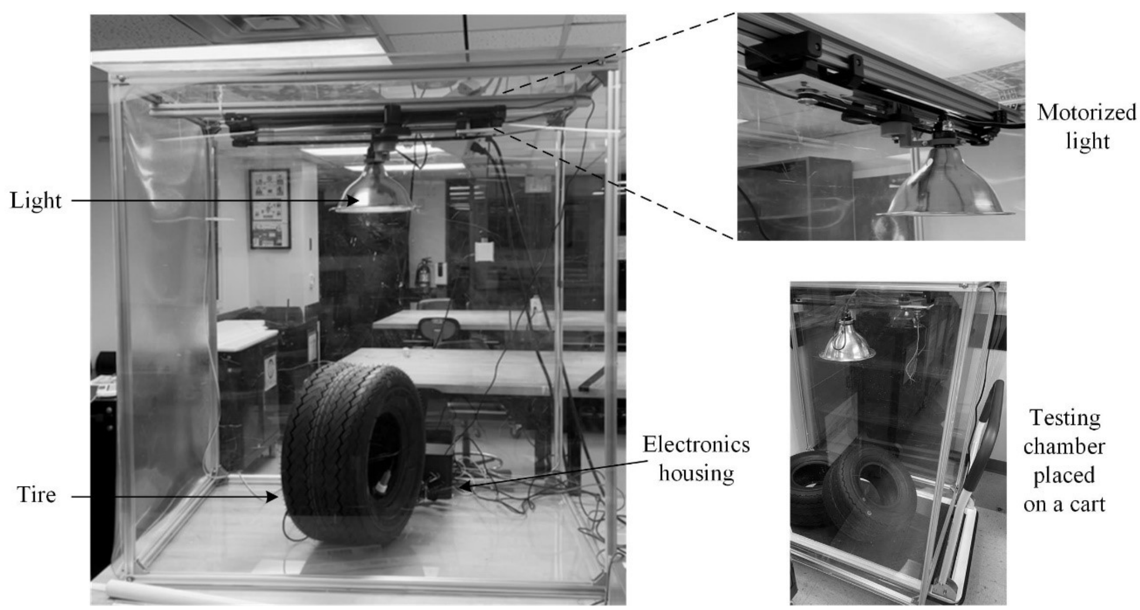


**Figure 3. Mechanical system (A picture on the left, the motorized light on the top right, and the placement on a cart on the bottom right)**

For the further testing, this test chamber may need to placed outside of the laboratory. For this reason, this instrumentation was designed to be mobile by placing on a cart as shown bottom right of Figure 3. This placement on a cart is effective since it can be easily relocatable as needed. There are two tires placed inside the chamber, and this specific dimension of the chamber was optimized up to two tires.

### C. Software design

Software architecture is shown in Figure 4. For the BeagleBone Black board, the high level of the program is shown and the code was written using Python language. First, various sensors are accessed and measured. Next, the collected data can be sent to Azure service. The data can be accessed by a GUI program that was using the .NET framework.

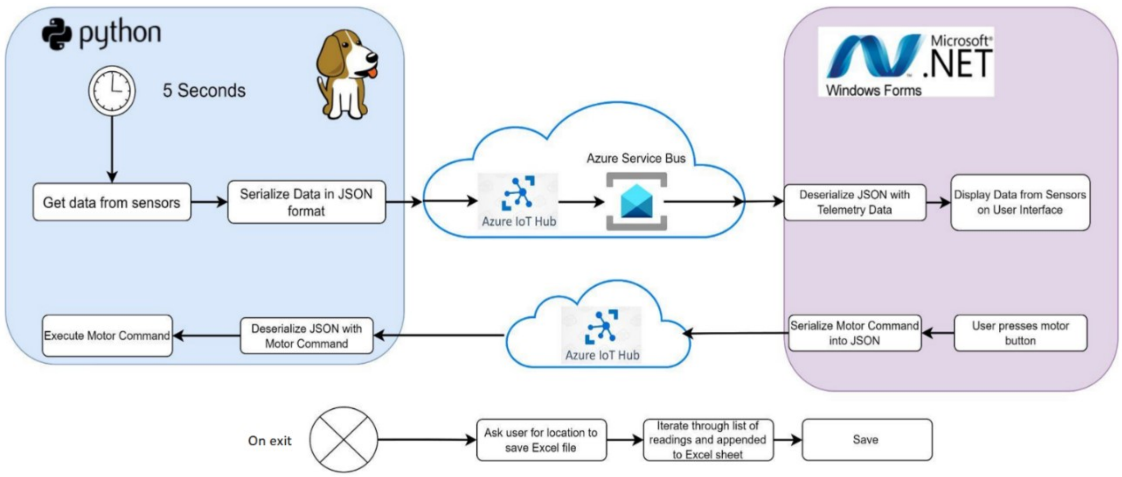


**Figure 4. Software architecture of a mosquito breeding environment testing instrumentation**

Moreover, for the GUI program, the control data for the motorized light can be sent to the Azure service. The BeagleBone Black board can receive the control data and execute the relevant motor command. This IoT (Internet of Things) system is an effective method if the chamber would need to be placed at a remote test site and a user needs to access the data remotely.

### D. Tests and Measurements

Tests and measurements were performed as shown in Figure 5. On the left side, it shows the picture of the system in testing. On the top right side, it shows the laptop screen executing the GUI program. The GUI program can display sensor data and it can send the motor control data. The measurement panel from the GUI program shows data such as $CO_2$, Ambient temperature, Humidity, pH level, Water temperature, and Ambient light.

On the right side of the measurement panel, it shows the buttons for motor control. A user can press Up or Down button to control the position of the light. This device has limit switches for protection. The mobile light fixture cannot be controlled to exceed a certain range.

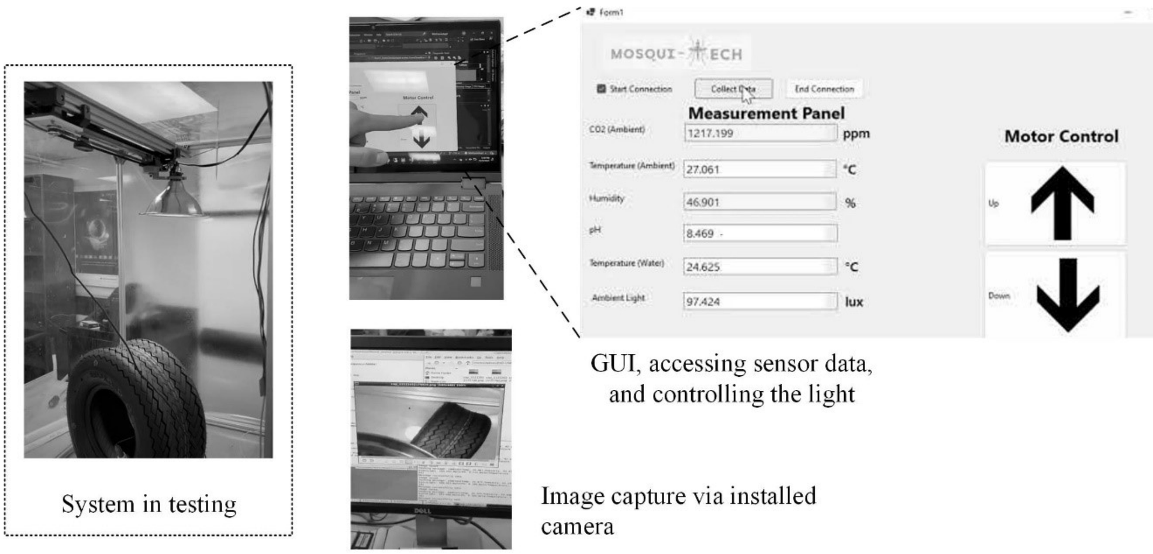


**Figure 5. Testing and Measurements (System picture on the left, Sensor data on GUI on the top right, and captured image on the bottom right)**

On the bottom of Figure 5, it shows a computer screen displaying an image data. A USB camera is installed on the top of the chamber of the instrumentation, and the camera images can be accessed via BeagleBone Bone Black board. The images can be captured and stored on the microSD card. The image data can be stored periodically at a defined interval.

## IV. Educational value

This capstone project was started in Spring 2022 and it was concluded in Fall 2022. During the project period, students have shown a strong dedication to the completion of the given project. As it was mentioned, this capstone project shows interesting diversity and inclusion. A majority of the students are Hispanic students and 40% of the team members (Two out of five students) are female engineering students.

As a technical advisor of several prior capstone projects, there are a couple of general lessons learned while advising this capstone project. First, as a technical advisor, given this diversity, the role of the advisor may need to be intentionally more attentive and sensitive to the student's needs. In addition, this project is related to the design of an innovative prototype device and it might have required coming up with a new solution. Thus, students might have faced unexpected challenges during the project period. Second, this capstone project is a two-semester project, and the second semester is typically the more intensive semester for students. It is recommended for the technical advisor to observe and watch students' performance closely and carefully to determine the need for intervention to diagnose and assist to solve their technical problems. Third, throughout this specific capstone project, the team experienced challenges related to an unexpected shortage of key electronic parts. For this reason, the team had to choose an alternative part. For instance, the BeagleBone Black board was not initially their first choice as the intelligence unit. Due to the shortage of the popular Linux-based single-board computer, the team decided to use this BeagleBone Black board, which helped the completion of the project. However, the team had to put an extra effort into learning a new computing environment and programming that they are not familiar with on the student's side. Moreover, there were sensors that were not available or difficult to obtain. The student team showed the resilience to find alternative parts to continue to conduct research and development. Lastly, for the educational value, overall, this project was completed successfully. All five undergraduate students graduated. Two of them decided to stay to join the graduate school at this same institution. This project served them to continue to pursue advanced degrees. Two out of five, 40% of the students joined graduate school, and the rest of the students joined the industry.

## V. Discussion & Concluding remarks

A mosquito breeding environment testing instrumentation was introduced, and it was developed through a capstone project. This development task was carried out for two academic semesters Spring 2022 and Fall 2022. The capstone project was completed, and the research and development on this work are planned to be continued. For a technical advisor, there were lessons learned related to a capstone project team showing diversity and inclusion. From the student's side, they have learned engineering skills via this experiential learning process. The further development of this task can assist in advancing an understanding of the stagnant water properties related to the abandoned tires that are potential mosquito breeding spots. The authors plan to continue to pursue this research and to extend the study and applications using this mosquito breeding environment testing instrumentation platform.

## Acknowledgments

A water sampling rover and the system was presented and it was carried out via a capstone project. The capstone project was completed in Fall 2022. The research and development of this work are planned to be continued. The further development of this task can assist in advancing and understanding the mosquito populations for the potential mosquito breeding spots. The authors plan to continue to pursue this research and to extend the study and applications of mosquito breeding environment testing instrumentation.

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