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IoT Environmental-monitoring System Development for Mosquito Research Through Capstone Project Integration in Engineering Technology

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Abstract

Mosquitos can be dangerous because they can transfer viruses and parasites to animals and humans. These harmful agents include West Nile, dengue, Zika, and parasites such as Malaria. For mosquito research, climate data and environmental conditions can be used in studying the effect on the breeding sites of the mosquitoes and the mosquito population control. Microclimate conditions can be monitored for better resolution of the analysis and deeper understanding of the effect on human lives. In order to obtain the microclimate data, a custom mosquito environmental monitoring system has been in development. This system is based on a platform of an internet of things (IoT) system. To extend and broaden the impact in engineering education in this research area, three capstone teams on this IoT environmental monitoring systems development for Mosquito research were formed in the Fall of 2020. Each capstone team was given one task. These tasks include creating a mobile weather station, a Raspberry Pi cluster, and a water sampling drone for mosquito research. This paper provides the details of the efforts in the integration of three capstone projects for mosquito research. Moreover, feedback and surveys from the students were collected and discussed in this paper.

I. Introduction

Mosquitos can be dangerous because they can transfer viruses and parasites to animals and humans. The harmful agents include West Nile, dengue fever, Zika, and parasites such as Malaria[1,2,3]. Mosquito research and mosquito population control may save lives from vector-borne diseases. For mosquito research, climate data and environmental conditions can be used in studying the effect on the breeding sites of the mosquitoes. The data can also be used in mosquito population control. While macro weather data is useful, it may not necessarily provide accurate data at a specific location[4,5]. Thus, microclimate conditions may need to be monitored for the better resolution of the analysis and deeper understanding of the effect[6,7].

For the measurement and monitoring of microclimate environmental data, the development of a custom environmental monitoring system for mosquito research has been in progress by the multidisciplinary research team from three departments: Entomology, Engineering Technology, and Industrial and Systems Engineering at Texas A&M University. An Engineering Technology team at Texas A&M University has been working on the engineering aspect of the research project. In order to expand and broaden the impact of this research as well as on engineering education, three capstone teams were formed to develop parts of the IoT (Internet of Things) environmental monitoring system for Mosquito research. A total of 12 undergrad engineering students have been working on these capstone projects. Each capstone team is composed of four undergraduate students. In addition, two graduate students have been involved as graduate student mentors to assist this effort. A capstone project in Engineering Technology at Texas A&M University is a two-semester project. These three engineering capstone projects for mosquito research were completed in Spring 2021.

The names of the three capstone teams are Big Dog Engineering, AIM-N (Autonomous Integrated Monitoring Network), and Pond Hoppers. In this paper, they are also referred to as Capstone team 1, Capstone team 2 and Capstone team 3, respectively. Capstone team 1 (Big Dog Engineering) is creating a mobile weather station. Weather stations that have been typically used in mosquito research. Generally, they are stationary instrumentations. However, this weather station is mobile, and it can navigate to a targeted location and perform the measurement. After the completion of the monitoring task, it can return to the specified location. Moreover, Capstone team 2 (AIM-N) is creating a customized IoT network and a cluster server to process collected sensor data and to perform data analysis including machine learning. This team is creating a primary server that is a low-cost cluster server using Raspberry Pi compute modules as well as the remote servers that can be used in forming a network to collect the sensor data and image data. Furthermore, Capstone team 3, (Pond Hoppers) is creating a drone to monitor water data and collect a sample from standing water. Monitoring water data and water samples are needed to understand the condition of mosquito breeding sites. For this purpose, this customized quadcopter that can float on the water and monitor water conditions has been in development.

The details of the multiple facets of the integration effort of teaching and research as well as the combination of multiple capstone projects for mosquito research, are presented. The feedback and survey from the students have been conducted in May 2021, and the data and the analysis are also presented in this paper.

II. Environmental Monitoring IoT System for Mosquito research

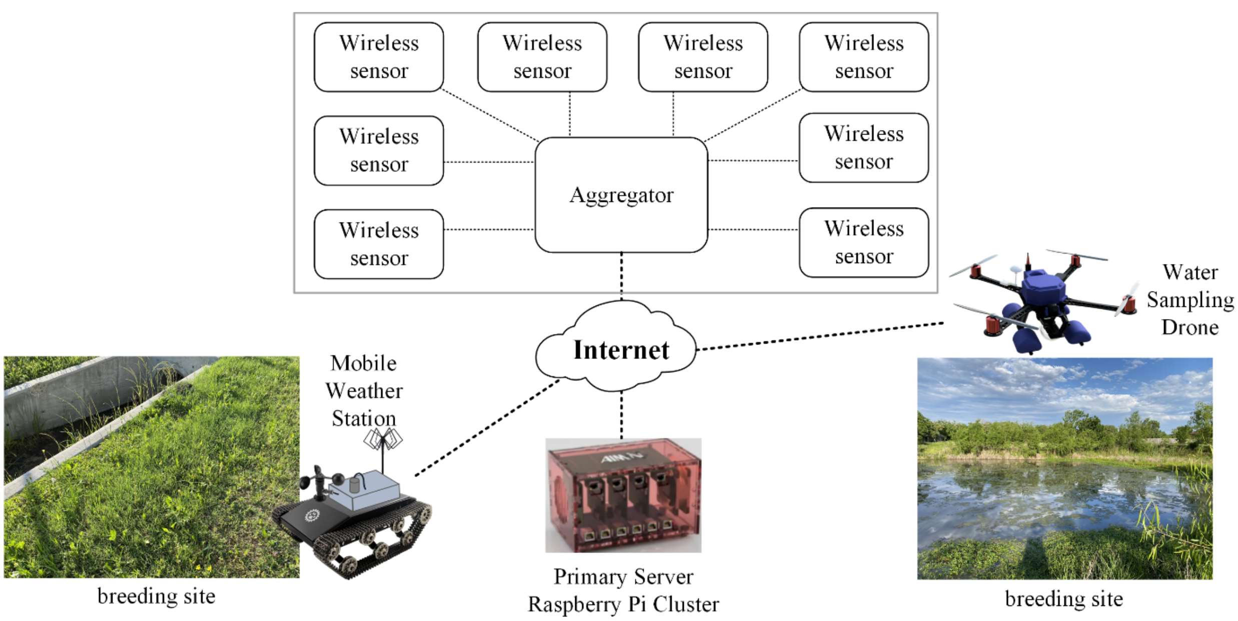

Figure 1. A conceptual block diagram of a multi-resolution solution for mosquito research.

A microclimate sensor network for mosquito research has been in development as a part of a multi-disciplinary research project. There have been several revisions of this monitoring system over the several years on this research. The wireless system is shown on the gray box at the upper portion of Figure 1. Each wireless sensor is a unit that can be deployed in the field to collect microclimate data. Although the diagram shows a limited number of wireless sensors as an example, this does not set the limit of the wireless sensors that can be connected to the network. There is an aggregator unit that can receive the data and upload the data to a server. This is a part of the effort in this multi-disciplinary research project. The researchers and the students from Electronic Systems Engineering Technology (ESET) and Multidisciplinary Engineering Technology (MXET) programs in Engineering Technology have been conducting research and development on this multidisciplinary research project.

To expand the impact of this research, three capstone projects were formed to tackle this engineering project for mosquito research. On the left side of Figure 1, it shows a conceptual model of a mobile weather station. Capstone team 1 (Big Dog Engineering) has been building this device. This mobile weather station can be dispatched to measure the environmental conditions at a remote location of a possible breeding site. The measured sensor data can be uploaded to a server. To implement a server, Capstone team 2 (AIM-N) has designed a customized IoT network in the form of a Raspberry cluster. The conceptual model of this network server is shown on the lower center side of Figure 1. Moreover, a water condition at a possible breeding site can be monitored using a customized water sampling drone. The conceptual model is shown on the right side of Figure 1. These collective efforts can form a full spectrum resolution monitoring system for mosquito research.

III. Integrated Effort of Capstone Projects for Environmental Monitoring IoT system

A capstone experience in Engineering Technology is an important piece of engineering education. Senior students are given an opportunity to conduct research and development with faculty members. As it was mentioned, three capstone projects were formed and started in Fall 2020. These teams successfully concluded their capstone projects in Spring 2021. Interestingly, these two semesters were not typical capstone semesters because of COVID-19. The mode of operation for the school have been limited. Also, capstone operations were also affected. Due to COVID-19 during this period, weekly research meetings were held over Zoom (On-line conference platform) for Fall 2020 and Spring 2021. The following subsections introduce more details about these three capstone projects.

A. Capstone team 1 (Big Dog Engineering)

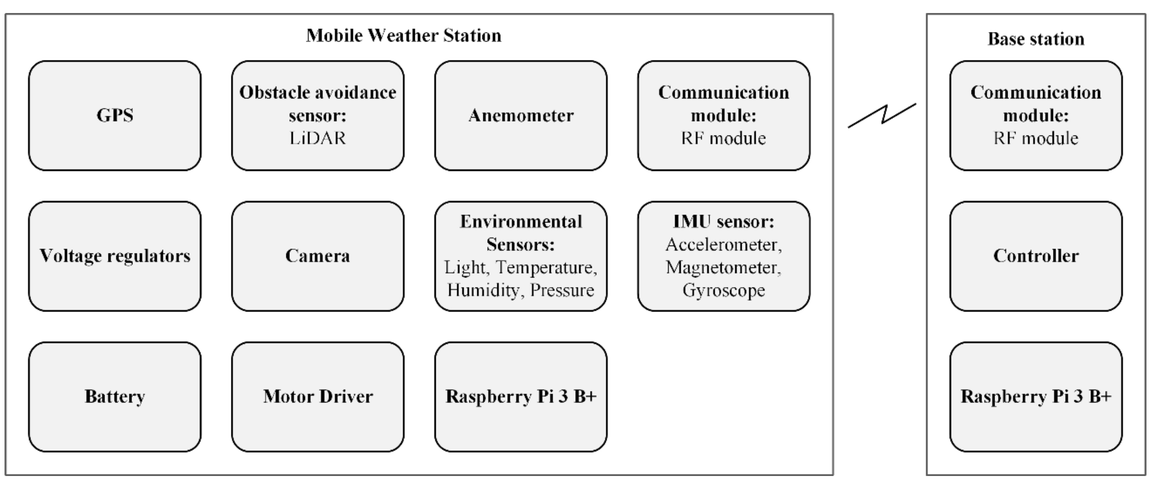

Figure 2. A block diagram of a mobile weather station

This small mobile weather station in development is capable of being deployed for microclimate data measurement missions at mosquito breeding sites. A conceptual block diagram of the mobile weather station is shown in Figure 2. This mobile weather station can measure light, temperature, humidity, pressure, and wind speed. For navigation, it has GPS (Global Positioning System), IMU (Inertial Measurement Unit), and LiDAR (Light Detection and Ranging) sensors. The mobile platform is a tracked vehicle. A motor driver controls two motors for tank tracks. A Raspberry Pi 3B+ board is used as a main computing unit. The data on the mobile weather station can be sent over to the base station, and it can be uploaded to a server. The mobile weather station was built as shown on the right side of Figure 3. On the left side, the base station that can control the mobile weather station is shown.

Figure 3. Picture of the mobile weather station and the base station that can remotely control the mobile weather station.

B. Capstone team 2 (AIM-N)

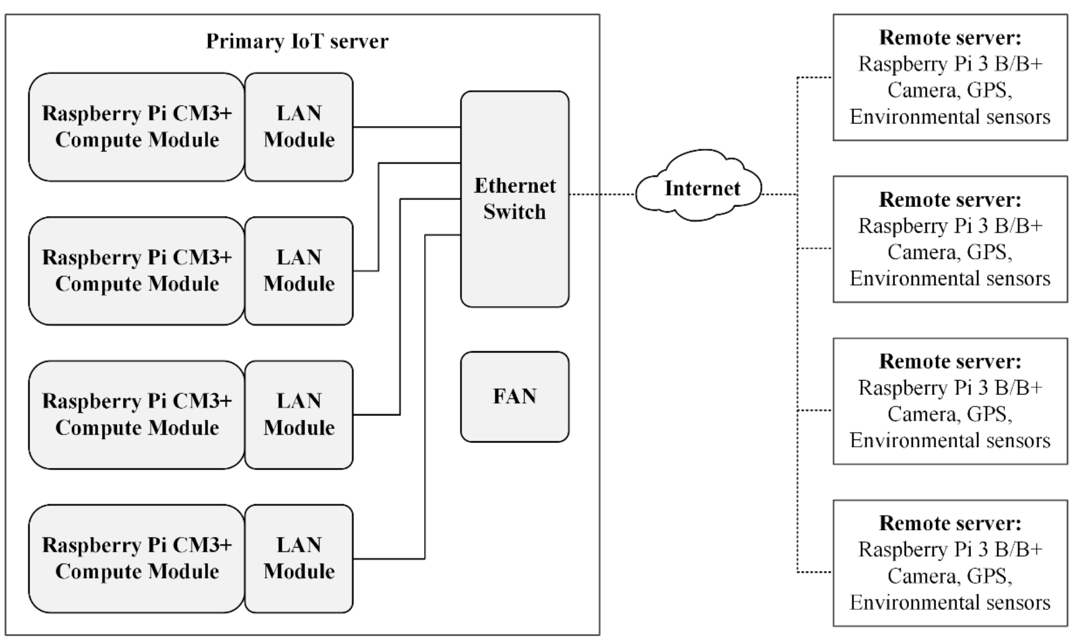

Figure 4. A block diagram of a Raspberry Pi Cluster and testing network

This IoT system uses a server for data analysis, including machine learning. A low-cost cluster-based server has been in development. It is based on multiple Raspberry Pi CM3+ compute modules. They form a cluster to process and handle the web services for the microclimate data and machine learning. This customized data server can collect data from the sensors and remote servers, and it provides a web service for users to access the data. A block diagram is shown in Figure 4. On the left side, there is a box named "Primary IoT server". It has four Raspberry Pi CM3+ compute modules, and they form a cluster[8]. On the right side, four Raspberry Pi 3 Model B/B+ are shown. They are used as remote server nodes to test this network. This customized Raspberry Pi Cluster was built and shown on the left side of Figure 5. The screenshot accessing the sensor data and the location is shown on the right side.

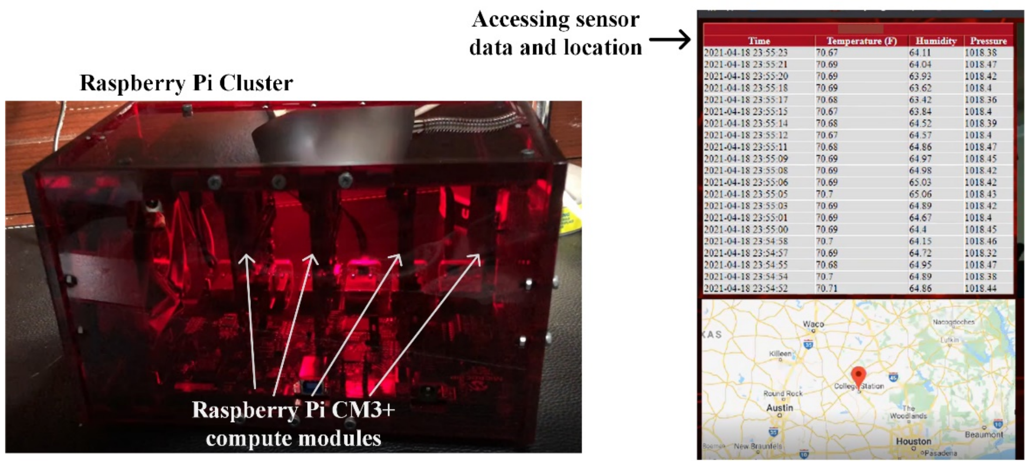

Figure 5. Pictures of the custom raspberry cluster and the screenshot showing sensor data and location.

C. Capstone team 3 (Pond Hoppers)

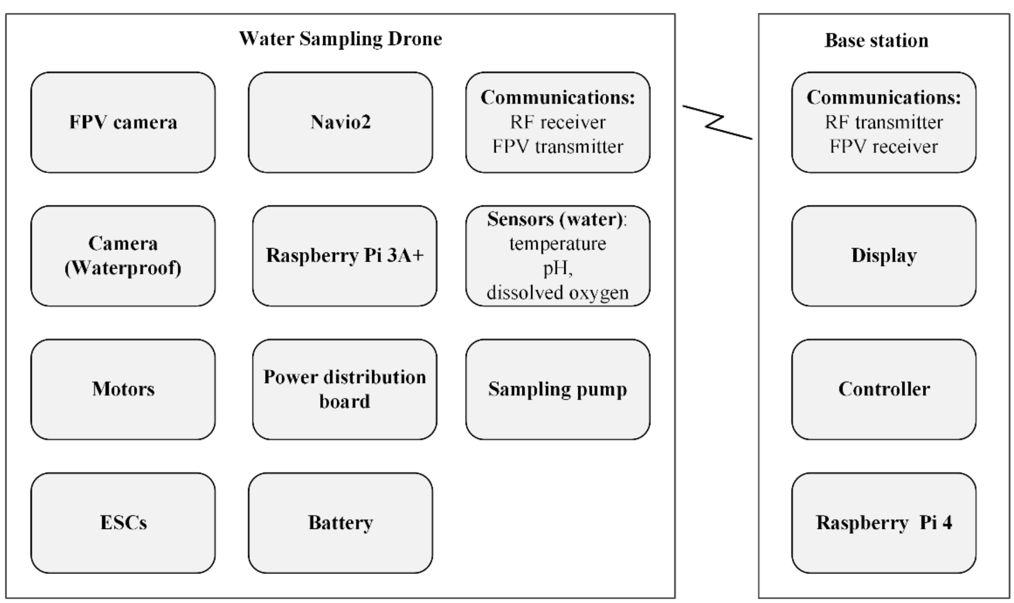

Figure 6. A block diagram of a watering sampling drone.

Standing water may need to be monitored for mosquito control[9,10]. Moreover, water samples need to be collected for further analysis to track mosquito breeding site status and patterns. For this purpose, a customized drone has been in development. A conceptual block diagram of this water sampling drone is shown in Figure 6. The water sensors include temperature, pH, and dissolved oxygen sensors. The drone has a pump that can collect a water sample. This device would be useful in surveying a standing water resource at a remote location. A Navio2 is an expansion board for a Raspberry Pi board. A Navio2 was used to provide the pilot operations and functions[11,12]. The autonomous control of the drone can be performed via mission planner software.

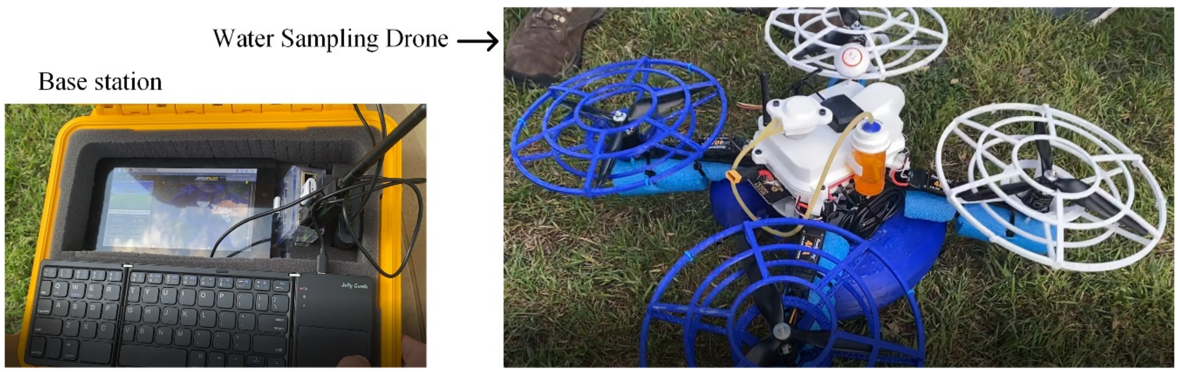

Figure 7. Pictures of the water sampling drone and the base station

The picture of this water sampling drone is shown on the right side of Figure 7. It has been tested for the water sensor measurements and the collection of a water sample. A base station is shown on the left side. It can control the water sampling drone.

IV. Capstone Project Evaluations

The post capstone evaluation was performed. It was conducted after the completion of the capstone courses. The on-line anonymous survey invitations were sent to the students who have been involved in three capstone projects. Specifically, the invitations were sent to 12 undergraduate students and 2 graduate students who served as student mentors. The on-line survey questions were shown as follows:

1. Did this Capstone project enhance your learning about relevant technical skill sets?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A
5	4	3	2	1	0

2. Did this Capstone project enhance your learning about working in a team environment?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A
5	4	3	2	1	0

3. Do you think Capstone will be beneficial to your current or future career?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A
5	4	3	2	1	0

4. Do you think the organization of the three capstone teams for the mosquito research themes effective?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A
5	4	3	2	1	0

5. Did COVID-19 affect your capstone project

Strongly agree	Agree	Neutral	Disagree	Strongly disagree	N/A
5	4	3	2	1	0

6. If your answer to the prior question is "agree" or "Strongly agree", describe what has affected your capstone project due to COVID-19.

7. Briefly state the lessons that you have learned throughout this Capstone experience.

This survey was created and conducted using Qualtrics. This voluntary survey was designed to ask a few questions related to the educational impact and their feedback related to their capstone experience. “Anonymize responses” option in Qualtrics was used. This option was described as “Don’t record respondents’ IP Address, location data, and contact info.” from Qualtrics. The summary of this post Capstone survey results is shown in Table 1. Most of the students (71%) have participated in the survey. Participants have shown positive responses toward their capstone project related to the technical skills (Q1, Average: 4.8), teamwork (Q2, Average: 4.9), and their impact on their career (Q3, Average: 4.7). For the question related to the organization of the three teams for the mosquito research theme was also positive according to their feedback (Q4, Average: 4.2).

Table 1. The post capstone survey results for three capstone teams of Big Dog Engineering, AIM-N, and Pond Hoppers teams

Survey participation rate	71% (10/14)
1. Did this Capstone project enhance your learning about relevant technical skill sets?	4.8 (Average)
2. Did this Capstone project enhance your learning about working in a team environment?	4.9 (Average)
3. Do you think Capstone will be beneficial to your current or future career?	4.7 (Average)

4. Do you think the organization of the three capstone teams for the mosquito research themes effective?	4.2 (Average)
5. Did COVID-19 affect your capstone project?	4.0 (Average)
6. If your answer to the prior question is "agree" or "Strongly agree", describe what has affected your capstone project due to COVID-19. *Summary of the selected answers:* ** Availability of the parts and use of the school facilities.* ** Attending meetings remotely and working separately.* ** Forced on-line communication due to COVID-19. * Scheduling times for meetings* ** Lack of in-person collaboration * It became hard to work together in person*	
7. Briefly state the lessons that you have learned throughout this Capstone experience. *Summary of the selected answers:* ** Project management, time scheduling, professional communication, product development* ** How to work as part of a team and combine our efforts from different fields.* ** Effective communication between all team members involved in the development and design of a project * How to communicate and work as a team while we live in different locations.* ** Technical knowledge, lots of new topics had to be researched and utilized to complete this project. * How to apply my leadership experience into managing a successful project.* ** Overcoming challenges such as not being able to meet in person, passing off parts, etc.*	

From the survey results, the COVID-19 affected the team (Q5, Average: 4.0)[13,14]. The reasons were asked in Question 6, and it was summarized and analyzed as follows. Students were limited in using parts and spaces at the school during this project period. The regular meetings were forced to be held remotely. Students can work together at the school, but there are regulations and limitations related to the COVID-19. Some students could not meet their team members regularly because some of them reside in other cities. The lessons learned through the capstone experience were asked in Question 7. Students seemed to have learned about the importance of communication between team members as well as the importance of teamwork. Moreover, some students have learned about the importance of project management and leadership. Due to the COVID-19, students tend to perform their work at their own residence. So, most of them did not regularly come to the school due to the COVID-19. But, they needed to come to the administrative office to receive their parts that they had placed an order for. It may have caused difficulty in their smooth capstone experience. In the end, students were able to manage to overcome many challenges like these due to the COVID-19 during their capstone project.

The total number of capstone teams in their second semester was 23. Three capstone teams have worked on this integrated project. This was about 13% of the total number of capstone teams. Three teams have worked on quite different project topics, but their goal is related to developing an integrated IoT monitoring system for mosquito research.

V. Discussion & Concluding remarks

Vector-borne diseases can cause illnesses that can be fatal to some people. The effort of conducting research on Vector-borne diseases and Mosquitos is planned to be continued. The IoT monitoring system can perform data collection, including environmental data related to the mosquito breeding sites. The researchers have worked for the development of the customized IoT system for mosquito researchers. In order to expand the impact, research and teaching efforts have been integrated. Three capstone projects have been created in Fall 2020. They have designed a mobile weather station, a Raspberry Cluster server, and a water sampling drone for mosquito research. These capstone projects concluded in Spring 2021. It was found that there were synergies in creating projects in a common theme. Three teams had significant differences. It turned out that the integration of three capstone projects was possible, as three capstone teams have successfully completed their tasks. The authors plan to continue researching to advance the engineering and technology for mosquito research and mosquito control.

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