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Development of Amphibious Water Sampling Rover for Mosquito Research via Capstone project

Dr. Byul Hur, Texas A&M University

Dr. B. Hur received his B.S. degree in Electronics Engineering from Yonsei University, in Seoul, Korea, in 2000, and his M.S. and Ph.D. degrees in Electrical and Computer Engineering from the University of Florida, Gainesville, FL, USA, in 2007 and 2011, respectively. In 2016, he joined the faculty of Texas A&M University, College Station, TX. USA, where he is currently an Assistant Professor. He worked as a postdoctoral associate from 2011 to 2016 at the University Florida previously. His research interests include Mixed-signal/RF circuit design and testing, measurement automation, environmental & biomedical data measurement, and educational robotics development.

Nathan Alexander
Mr. James Kyle McIlhaney
Christian Hurst
Leo Colom

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Abstract

Mosquitos may lay eggs in shallow bodies of water near shore. Water samples may need to be collected for analysis, and manual collection of the water samples can be potentially a hazard to the personnel. For this reason, an amphibious water sampling rover was created by a capstone project team. This capstone project team was formed with five undergraduate engineering technology students. This project was started in the Spring semester of 2022 and concluded in the Fall semester of 2022. This project generated a rover, and the rover can navigate both on land and on water. And it can perform the water sample collection task. The rover can be controlled over a remote PC, and it can collect water temperature data, and the data can be sent remotely over the internet. For wireless communication, a sub-GHz LoRa module is used. The rover can also communicate over WiFi. A GUI (Graphical user interface) program was developed to collect data from the rover and to control the rover remotely. The GUI program obtains the GPS location of the rover and displays the location of the rover on a map. For the control of the rover, ROS (Robot Operating System) was utilized. A Raspberry Pi 3B+ board is used as an intelligence unit of the system. The collected samples can be brought to a laboratory for further analysis. In this paper, the details of the amphibious sampling rover and the educational lessons via this capstone project are presented.

I. Introduction

Mosquitos may lay eggs in shallow waters or wet areas near the shore of lakes, ponds, and rivers [1-3]. Although the exact location of where mosquitoes lay eggs depends on the mosquito species or the local environment available to the mosquitos, water is a necessity for the mosquito development. Once eggs are laid, often in a "raft" or cluster of 100-300 eggs, water is needed for the eggs to develop into larvae. Once the eggs become larvae, the larvae live mostly in water but near the surface to breathe air. Larvae will then feed, grow, and molt several times, typically four, growing larger with each molt. Mosquito larvae develop submerged just beneath the surface, which should allow for easily collecting larvae within water samples. In this aspect, water samples may need to be collected for mosquito analysis.

One of the major problems is related to the environments where mosquitoes breed. Often mosquito breeding grounds are hazardous. Local wildlife in these areas could include poisonous snakes, alligators, and other dangerous wildlife, all of which are dangerous for field scientists. Additionally, mosquitos themselves are known for transmitting diseases such as Malaria, Zika, Yellow Fever, West Nile Virus, and etc. To prevent mosquitoes from biting, scientists may wear suits in the field. However, these suits could be cumbersome to wear in the field, and these suits could be a problem for scientists due to the heat exhaustion.

For those reasons, manual water sample collection can be challenging. In order to tack this problem, a capstone project team was formed to create an amphibious water sampling rover. Being amphibious allows the rover to reach various areas where mosquitoes lay eggs such as shallow water near the shores and banks of lakes or swamps. The amphibious rover will take multiple water samples. Building the rover to take multiple water samples allows the user to be more efficient when collecting samples. Next, the user can control the rover wirelessly via the internet. Controlling the rover over the internet provides a method for the user to control the rover off-site and allows the users to send environmental data that the rover collects [4][5]. The environmental data includes humidity, water temperature, ambient temperature, and GPS location. The rover can be controlled using a "Long Range" (LoRa) gateway [6]. The LoRa gateway connects to the internet which receives and forwards data packets. In addition, the rover can be controlled using WiFi. Also, the rover is portable for the users to carry. The portable seized rover allows the users to bring the rover to the hard-to-reach areas where mosquitoes lay eggs. The development of this rover was tasked to a capstone project team of four undergraduate engineering students. In this paper, the details of the amphibious rover development via a capstone project are presented.

II. Capstone project management

Engineering students can earn more technical skills and understanding in their field though a capstone project. A capstone project is related to a method of experiential learning. For the capstone project in this paper, five Engineering Technology students formed a team. Five students can work for the common goal of the completion of the given project; however, they take on different roles in the team. In this project the roles include Project Manager, Hardware Engineer (Electrical), Hardware Engineer (Mechanical), Software Engineer, and System Integrations/Test Engineer.

This capstone team was created in Spring 2022. For Texas A&M University, the mode of operation was already back to in-person learning in respect to this capstone project period. The team had regular weekly in-person meetings with the faculty member. The name of this capstone project team was U.M.D (Unaccompanied Mosquito Detection). For this project, the first author in this paper, advised this capstone project. As a capstone project it was concluded in Fall 2022.

III. Amphibious Water Sampling Rover for Mosquito research

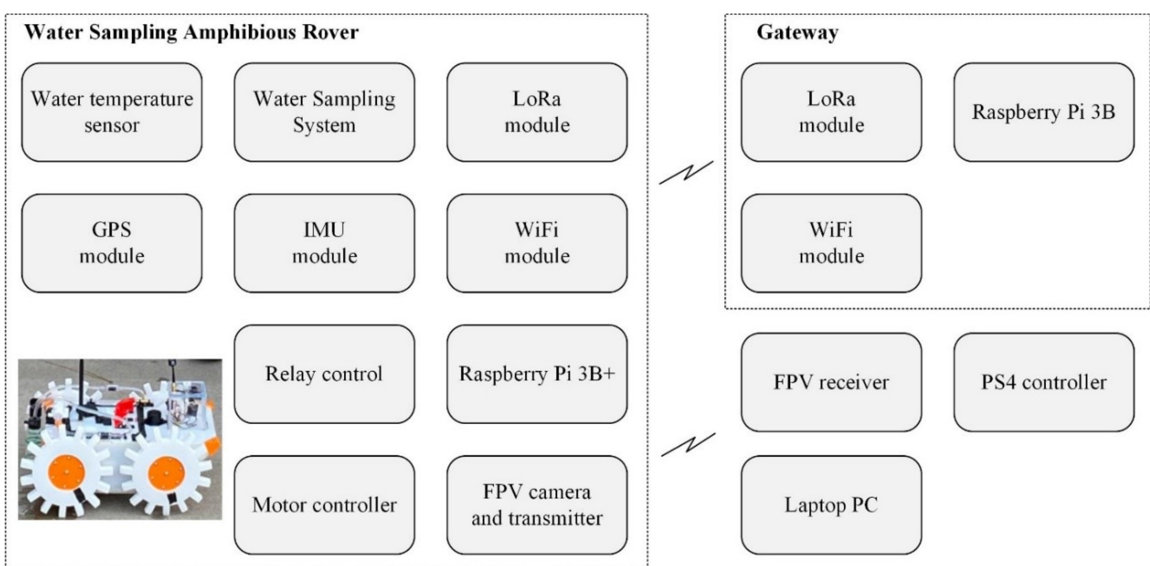

Figure 1. Conceptual Block Diagram

The conceptual block diagram of the water sampling amphibious rover is shown in Figure 1. The water sampling rover is shown on the right side and the gateway and the laptop PC is shown on the right. For the water sampling rover on the left, it includes water sampling system and water sensor temperature sensor, Inertial Measurement Unit (IMU) sensor, LoRa/WiFi modules, and motor controller. For the main controller unit, a Raspberry Pi 3B+ board is used, and this specific model of the Raspberry board was found to be suitable for this project. For the communication units, a sub-GHz Lora module is used. And the rover can also communicate over WiFi. A gateway unit is shown on the left side. The gateway unit supports the sub-GHz communication. It can communicate with the rover using a LoRA module, and it can send and receive the data over internet for remote access and control. The laptop PC can access the data over the internet. To assist the navigation, FPV (First Person View) camera transmitter and receiver system are used. This camera system can assist to drive the robot to a remote place where the operator does not have a direct sight of the rover.

A. Hardware design

The functional block diagram of the water-sampling amphibious rover is shown in Figure 2. The custom PCB is shown on the bottom side, and it includes a GPS module, IMU sensor, and LoRa module. The water sampling system is shown on the left side. The portion of the motor driver and drivetrain is shown on the top. The gateway is shown on the right side.

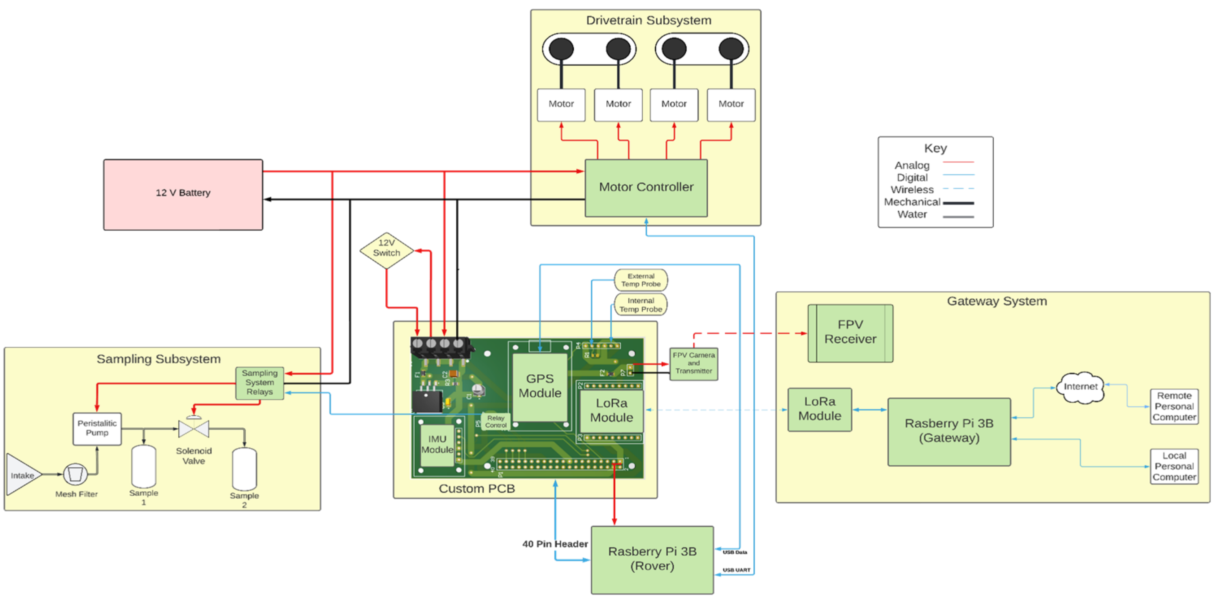

Figure 2. Functional Block Diagram

The electronic system is shown in Figure 3. The picture of the electronic boards is shown on the left side. The custom PCB is located in the middle of the stacked boards. The relay component that can control the flow of the water is located at the bottom, and the motor driver is also placed at the bottom. The layout of the custom PCB is shown on the right. This is the board that is stacked on top of the Raspberry Pi 3B+ board. A water temperature sensor such as RTD sensor is connected through this PCB as shown on the bottom right side.

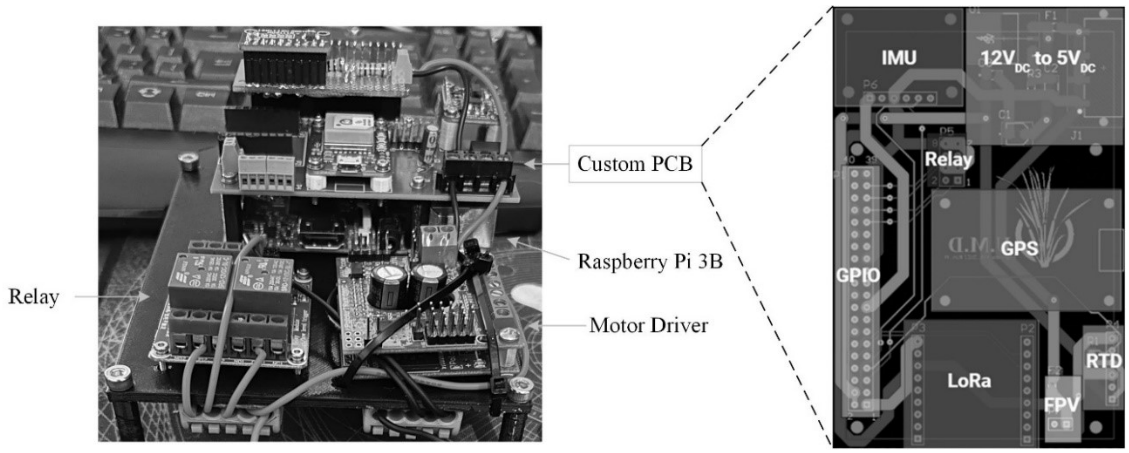

Figure 3. Electronic system (A picture on the left and the board layout on the right)

B. Mechanical Design

The capstone students considered several options for the amphibious operation. The initial mechanical design model was based on extended tank treads that are used as flappers in the water to propel the tank and work as standard tank treads on land. Next, the team designed a four-wheel type that can work in the water and on the land as shown in Figure 4.

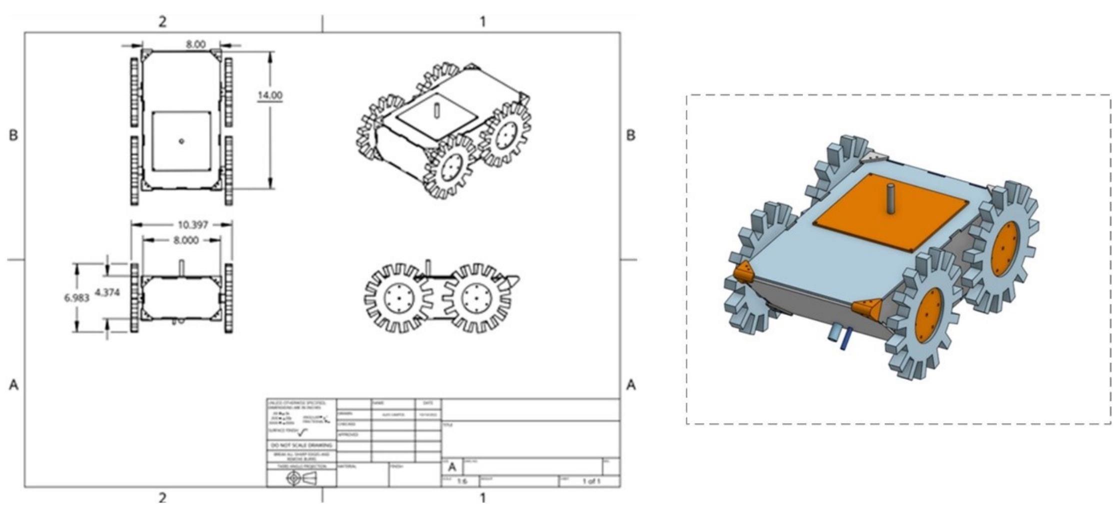

Figure 4. Mechanical design (Drawing on the left and 3D model on the right)

The drawing of the rover is shown on the left side, and the 3D model is shown on the right. The robot chassis was designed to be waterproof for the bottom and the sides. There is an opening on the top. The robot needs to be open on several occasions, for instance, in case of battery replacement.

C. Software design

The Robot Operating System (ROS) is a middleware suite to help researchers and developers build and reuse code for robotics applications [7-9]. This water-sampling amphibious rover system was designed based on the ROS. Programs were written in Python language using ROS [10-12]. The ROS dataflow is shown in Figure 5.

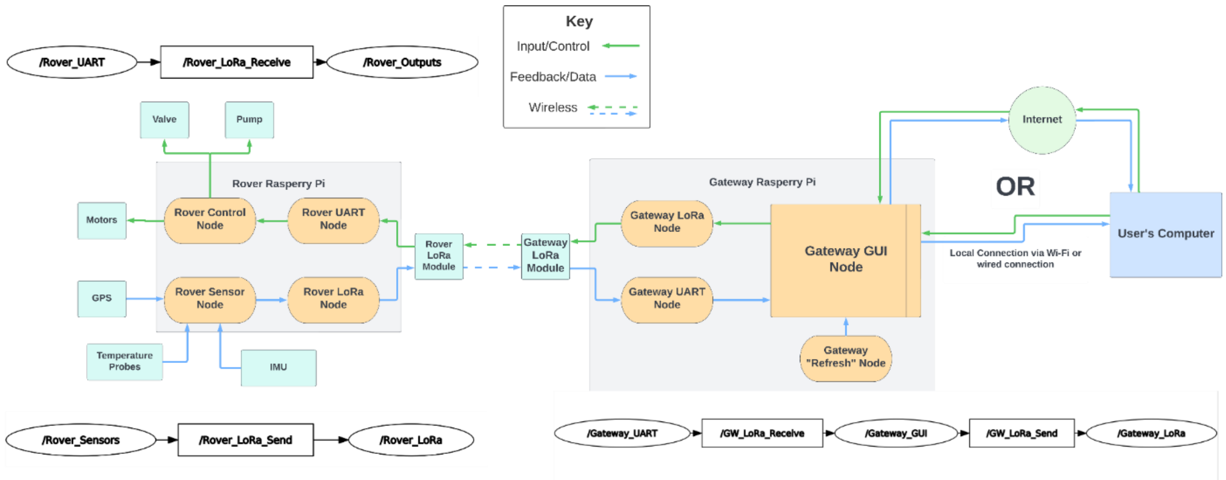

Figure 5. ROS dataflow

On the left, it shows the Rover and the gateway is shown in the middle. The GUI program was described in the right side. This dataflow shows the publish and subscription of ROS topics across the rover, gateway, and the GUI program [13-14]. For the rover side, the camera, communications, drive system, sampling system, and sensors are processed as described in the dataflow. The sensor data can be viewed and the rover can be controlled via the GUI program.

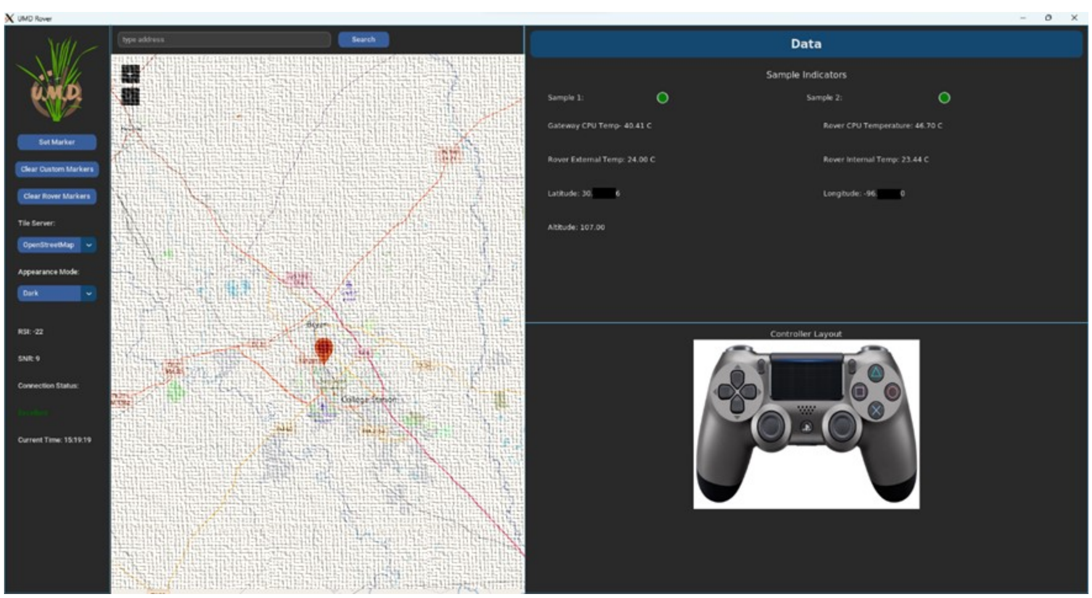

Figure 6. GUI development

The GUI program is shown in Figure 6. This GUI program was designed to provide users to control various functions of the rover. On the right side, it displays the rover status and sensor data such as water sampling status, temperature, and GPS locations. On the left side, it displays the map and the GPS location of the rover can be displayed as a marker. Lastly, the PS4 controller is shown on the bottom right. A PS4 controller can be connected to the user's PC and it can control the rover remotely.

D. Tests and Measurements

For testing the water-sampling rover system, various functions were verified and tested inside the laboratory as shown on the left side of Figure 6. For an indoor environment, a GPS signal may not be picked up and settled nicely. Except this problem, a majority of the functions were able to be tested and verified indoors. For the driving test, the robot was brought to the outside of the laboratory. The driving test was shown in the middle of Figure 6. For this driving testing, a WiFi communication method is selected. The rover can be controlled remotely over WiFi by exchanging the ROS topics.

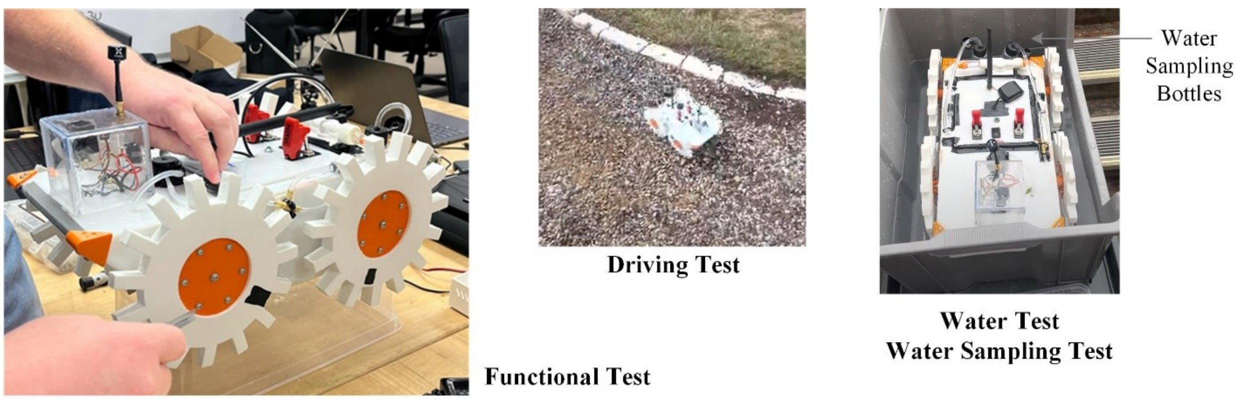

Figure 6. Testing and Measurements (Functional test, Driving Test, and Water test)

For the water test, a plastic container was used as shown on the right side of Figure 6. The rover was placed inside this container that is filled with water. While the rover floats, the user can control the rover to verify the maneuverability of the rover. Next, the water sampling function was tested. Water samples were collected and filled the two water sample bottles.

IV. Educational impact and lessons

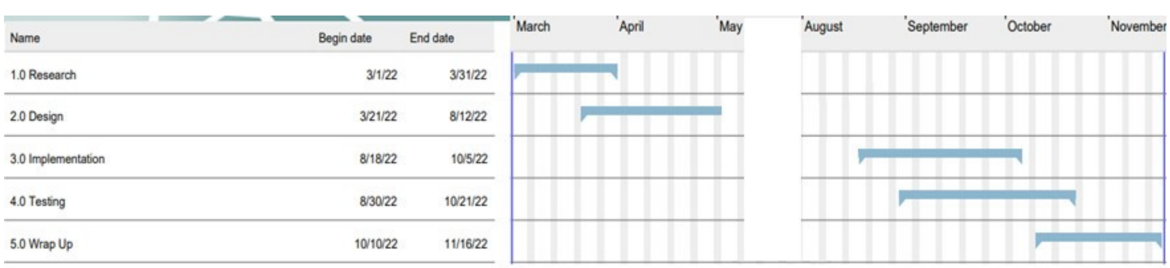

Figure 7. A part of the project schedule (Spring 2012/Fall 2022)

This capstone project was started in Spring of 2022 and it was concluded in Fall of 2022. For this capstone project, students took an Engineering Technology Capstone I course in Spring 2022 and an Engineering Technology Capstone II course in Fall 2022. A part of the project schedule is shown in Figure 7. The project was organized and managed by higher-level categories of *Research*, *Design*, *Implementation*, *Testing*, and *Wrap up*.

There are proposed milestones for this project created by students. The selected milestones for the second semester are shown in Table 1. The milestones include the completion of electronics, mechanical, and software implementations. These milestones were completed, and the table shows the status of the milestones and the dates. This capstone project successfully delivered a functional prototype as it was planned.

Milestones	Due	Status
Complete Mechanical and Electronics Implementation	9/15/22	*Completed*
Complete Software Implementation	10/5/22	*Completed*
Complete Mechanical Testing	10/13/22	*Completed*
Create Initial Fully Configured Prototype	10/21/22	*Completed*
Submission of Final Documentation	11/7/22	*Completed*
Final Prototype Delivery	11/16/22	*Completed*

Table 1. Selected milestones (2nd semester)

Students took the Capstone I and Capstone II courses. In addition to the technical and teamwork that they learned through the project execution, students also were learned and impacted by the course learning outcomes. For the course outcomes of the Capstone I course, students typically working in a team will achieve the following shortened/summarized learning outcomes:

(4-1) Form a team and conduct product development activities.

(4-2) Use project management concepts and toolset to create a comprehensive plan.

(4-3) Create and maintain team documents.

(4-4) Create the preliminary hardware and or software designs.

For the (4-1) outcome, one of the students was already working with the technical advisor prior to the capstone course. At the beginning of the capstone project, four students formed a team. One more student was joined later to the team during Capstone I, and the five students formed a team during the Capstone I course period. For the (4-2) outcome, students completed the planning of the project. For the arrangement of this specific project, the technical advisor asked students to identify and execute the major purchases during Capstone I course. Due to this request, students had to put an effort into obtaining detailed plans in the Capstone I course period. For the (4-3) outcome, students created the required documents successfully. For the (4-4) outcome, it is about a preliminary development effort and it helped the project execution in the following Capstone II course. After taking the summer break, students resumed this project through the Capstone II course. For the course outcomes of the Capstone II course, students also typically working in a team will achieve the following shortened/summarized learning outcomes:

(4-5) Manage the technical implementation of the planned project.

(4-6) Design, demonstrate, and deliver a fully functional prototype.

(4-7) Prepare, present, and critique oral presentations.

(4-8) Evaluate the contribution of team members.

For the (4-5) outcome, students continued the execution of the project as they planned. For the (4-6) outcome, students need to deliver a fully functional prototype. This is typically a challenging portion. Students delivered the functional prototype successfully at the end. There were some hurdles on the technical side. The description of the two of them will be followed. The first one is related to the method of a driving system. Initially, the team considered a tracked type with an additional flapping device for the generation of the water propulsion. Later, due to the imbalance between the two tracks, it was decided to switch to a four-wheel drive type with large gear holes for the water propulsion. The second one is related to the communication module. Initially, the project was planned to use a sub-GHz LoRA communication only. During the development, students experienced a hardware problem with the communication module. For this reason, it was decided to provide an additional communication method; therefore, a WiFi communication functionality was added to the project. Given modification and extra features, the students could deliver the functional prototype successfully. For the (4-7) and (4-8) outcomes, students participated in the presentations and evaluations for the Capstone II course.

The Capstone I course was assigned as a Special Course Designation for *Communication intensive*. The Capstone II course was assigned as a Special Course Designation for *Writing intensive* as well as *Communication intensive*. Students in this capstone project were impacted and learned how to write technical documents effectively and how to communicate and work in a team. As a technical advisor for the team, it was observed that the students were dedicated to carrying out the assigned capstone project throughout the project period. Moreover, students have demonstrated adaptation and advanced skills in technically challenging problems.

V. Discussion & Concluding remarks

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 using the water-sampling rover system.

Acknowledgments

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