East West University

Capstone Project Report

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DEVELOPMENT OF AN AUTOMATED SYSTEM FOR DETECTING CANNIBALISM AND WATER ECOSYSTEM MONITORING FOR CRABS

Consent Form

This capstone project titled **“Development of an Automated System for Detecting Cannibalism and Water Ecosystem Monitoring for Crabs”** was prepared by **Bijoy Basak ID- 2018-2-60-033, Simonta Chakraborty ID- 2018-2-60-036, Farhan Ahmed ID- 2018-2-60-111** submitted to **Dr. Mohammad Salah Uddin** for the fulfillment of the requirements of the Course CSE400C (Capstone Project) for B.Sc. in CSE offered by the Department of Computer Science and Engineering, East West University is approved for submission.

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Signature of the Supervisor

Date:

Declaration

We earnestly verified that the topic provided in this undergraduate capstone project is our unique work. We have not taken any parts of it without permission from other sources. It was completed by us and has never been submitted for an academic qualification, certificate, diploma, or degree to any other university, institute, or organization.

Acknowledgment

First and foremost, our deepest gratitude to the Almightily and All-powerful God, the creator, and ruler of all, the most merciful, who has given us the strength and ability to complete the project and project report successfully. We also express our unbounded gratitude to our capstone project supervisor Dr. Mohammad Salah Uddin, Assistant Professor, Department of Computer Science and Engineering, East West University, Dhaka, for his keen interest, inspiring guidance, and constant encouragement with our work during all stages, to bring this capstone project to fruition. We also thank our friends and families for their greatest support. Finally, we also thank the faculty and non-teaching staff members of the Department of Computer Science & Engineering, East West University for their valuable support throughout our university life and our research work.

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Abstract

Cannibalism and crucial water parameters of crabs are two major obstacles for the crab farmers to gain maximum yield when fattening in a pond. Our project aims to help minimize the cannibalism rate of crabs as well as to give farmers more control over their water. We created a machine learning model to identify possible crab sounds that are produced by crabs when they feel threatened or in danger. The model will notify the farmer when it detects crab sounds continuously. A water parameter monitoring system is also implemented which uses various sensors (temperature, pH, salinity, DO) to monitor the water parameters. When a parameter reaches or exceeds its tolerance level, the system notifies the farmer. There is a user interface that can be accessed to view all the system status and sensor readings. The project aims to give farmers more control over when they are fattening in ponds.

1. Introduction

The report aims to show a conceivable way of creating an automatic system for detecting cannibalism and a water monitoring system for crab farming. Crab farming is growing in popularity as the demand for crabs is increasing nationally and internationally.

Crabs are not delicate or prone to diseases as other fisheries, but they do need attention while fattening. Factors such as water, feed, climate, environment, etc. play a vital role in crab farming. Water quality and parameters are very crucial and feeding time and cannibalism can play a key role in the process. The type and amount of feed can affect the crab because without giving them the correct amount of food there can be a chance of cannibalism among the crabs as well as the water quite significantly. Feeding crabs depends on time or schedule and the quality and amount of feed is something that must be regulated. These can make the feeding process of crabs overwhelming for the farmers and any human error can significantly affect the crabs. So the chance of cannibalism rises. Because of the lack of food juvenal crabs can be eaten by the matured crabs. A solution to this problem can be a device that can detect cannibalism and notify the farmers during cannibalism and monitors the quality of water parameters regularly. Though both systems have been made by us, there has been no research or initiative in making such systems. To fill this gap, our paper aims to answer the following questions:

RQ (Research Questions): How will the system detect cannibalism and decrease it? What parameters of the water are most crucial?

In this report, we have shown a Machine Learning model for detecting crab sounds and real-time water parameters monitor.

Limitations: There are some limitations to our project and implementation at this point. For example, we could not test our implementation in the real world. Also, we could not test and implement various sensors as the water sensors became unavailable and expensive during the pandemic. However, it is possible to overcome these limitations in the future.

2. Related Works

Related works to our implementation:

1. Mohammad salah uddin et al.[1] build up an IoT device (Arduino Yun) to monitor water parameters. Their monitoring system integrates microcontroller base physical devices, IoT, and web applications. Their system allows users to remotely monitor a shrimp farm's water quality and it notifies when an out-of-range water parameter is detected.

2. Lorenna Parra et al.[2] implemented a low-cost Wireless Sensor Network (WSN) using an IoT device (Arduino Mega 2560) to monitor various water parameters and fish behaviors in aquaculture. They also implemented a smart algorithm to increase energy efficiency as well as an alerting system for abnormal water parameters. Their top achievement is fish presence detection. Their cost of implementation was 90 Euros. (Design and Deployment)

3. P. Y. Boon et al.[3] experimented with acoustic signaling and sound production of the sesarmid crabs Perisesarma Europe (De Man) and P. indiarum (Tweedie) from Mandai mangroves, Singapore. They found that the sound receptor, Barth's myochordotonal organ was present in both species. However, only the male crabs produced sound. They found that the crabs produce the sounds to communicate and produce noise to warn intruders or threats when they feel vulnerable. (Sound production in)

4. Jennifer and Maya et al.[4] found that ghost crabs produce sounds when they feel vulnerable and threatened. The crabs produce sounds with their gastric mills. The lateral teeth in the gastric mills of the crabs have a comb-like structure that rubs against each other to produce sounds. The dominant frequencies are below 2 kHz.

5. D. Mirera, Per-Olav Moksnens et al.[5] experimented with laboratory research to compare size class differences and the impact of shelter on cannibalism and limb loss in juvenile mud crabs. In a 48-hour test, four sizes of juvenile crab were tested in all possible combinations using four different substrates with distinct levels of protection. The results suggest that cannibalistic interactions are strongly influenced by both crab size differences and shelter availability. Cannibalism in the smallest class increased approximately 10 times in the presence of the largest crab compared with the same-size crabs. Their finding suggests that both sizing and serving shelters can minimize cannibalism in crab farming.

6. Arthur N. Popper, M. Salmon, Kenneth W. Horch et al.[6] reviews behavioral, physiological, anatomical, and ecological aspects of the sound and vibration detection of decapod crustaceans. They found evidence that some decapod crustaceans can recognize and use sound like the recognition and processing mechanisms of aquatic and terrestrial vertebrates. Some of them can be able produce sounds and many of them detect vibration in various aspects. Some semi-terrestrial crabs use sounds and produce them for communication purposes.

7. In another paper written by Tetsuya Sanda et al.[9] (2021), they experiment that cannibalism occurs when they do not get enough food.

8. A paper is written by Belgrad BA et al.[10] (2016) showed us the behavior of crabs which was measured with a metal prong that gives the food to crabs and observes the crab's response. From their paper, we found that crabs raised their chelipeds when they are hungry and moved away otherwise.

9. In Sound production and reception in mangrove crabs Perisesarma spp. paper is written by P. Y. Boon et al.[12], who experimented on the mangrove Perisesarma spp. And found them producing sound when any intruder gets into their territory.

10. "Inside Science", a popular science news website published a blog related to research about the Atlantic ghost crab producing sound when it gets annoyed or feels threatened [13].

From analyzing research studies, we will try to make a system by analyzing the sound produced by the crabs. The system will help prevent cannibalism. Along with this we also try to make a water monitoring system to continuously check the water quality by measuring various parameters of water.

3. Project Description

In this project, we are going to analyze the cannibalism behavior of crabs and monitor the water quality for crab farming in the pond. We will try to decrease the cannibalism of mud crabs by analyzing their behavior and using machine learning and IoT to implement a system that will help to increase the production of mud crabs. Along with the machine learning system to prevent cannibalism, there will be a continuous water monitoring system that will monitor the vital properties of the pond water and notify the farmer of any anomaly in water parameters. We will analyze the procedure of crab farming in the pond, the suitable water environment for crabs, and their behavior.

4. Project Rationale

In Bangladesh, crabs are one of the most commercially important food items as the environment of our country is perfectly suitable for cultivating crabs and the growth rate is extremely high as well. Mud crab farming is gaining popularity because of its high demand and high market price in the international market. So, in the southwestern districts of Bangladesh, the mud crabs are farmed widely, and the rate is increasing day by day.

In the 2017-18 fiscal year 85% of the exported crabs went to China. In the following year, crabs were exported worth 17.3 million USD globally. The later year it hit 43.1 million USD. But due to the global pandemic, the export to China was halted for a long time and the industry had faced loss. In the fiscal year 2019-20, almost 30 million USD worth of crab was exported worldwide [7] [8].

For crab farming, the size of the pond does not matter. Small ponds with an area of about 350 to 500 m2 are preferred as these kinds of ponds are more efficient to manage. The ideal depth of the pond is 1 to 2 meters and to prevent the crabs from escaping, the slope of the dikes should be steep. The dikes of the pond are made of mud blocks and fenced with bamboo mats which are 1.5 to 2 m high. Mats should be installed from 30cm deep into the mud to avoid crabs escaping during low tide. It will also prevent them from escaping by climbing over. The pond is treated with powdered lime of about 350 to 600 kg/ha and kept exposed to the sun for 5 to 7 days. Then the water is drained to a depth of 1.5 m in the pond. Water exchange is done daily or periodically by the effect of pumping or tides. Locally caught crab larvae are stocked at a rate of 3-5 crab/m2 at around 7 to 8 hours after two to three days of preparation. Trash-fish, soft-shelled snails, shrimp heads, and animal rubbish are regularly fed to the crabs. The most important food items of crabs are the soft-shelled snails from freshwater. The feeding rate of crabs is 7-10% of total body weight per day.

Enough food is given to the crabs for preventing cannibalism (the practice of eating the flesh of one's species).

Cannibalism behavior is found in the crabs. According to a study done by Tetsuya Sanda in 2021, they have found from their trial test that cannibalism occurs in 36.0% of the crabs. The occurrences of cannibalism are influenced by the body size of the crabs [9].

The higher percentage of cannibalism in ponds makes it less ideal than the cage fattening method. But most of the crab farmers in Bangladesh live in the coastal area. The farmers mostly use ponds to grow the crabs instead of cages as it is less expensive and requires less capital. In the coastal areas of Bangladesh, the lands are not suitable to cultivate crops. The salinity of water and land is not ideal for crop farming. So most of the farmers use their lands to create small ponds for fisheries such as crabs. Therefore, for them, cultivating crabs in ponds is more easier and efficient. So, to increase the profitability of the method and decrease the cannibalism rate among the crabs we selected this topic. The goal is to implement a system using machine learning and IoT. The system can be paired with any feeder which will ensure to feed the crabs when necessary and detect any chances of cannibalism.

5. Professional Expectations

Feeding, cannibalism, and lack of regular water monitoring are among the few reasons why crab farming in ponds is less profitable than farming in cages.

The system may become a key to preventing feeding problems and cannibalism. Regulating the feeding of the crabs is highly necessary because less food can increase the rate of cannibalism and excess food can cause water pollution and affect the growth rate of the crabs. The system can minimize the chances of occurrence and amount of loss from these problems.

On the other hand, the water monitoring system can help them to keep the crabs healthy and growing by providing them with real-time data and warnings about the properties of the water. This will save both the time and money of the farmers as they will not have to test the water as often by any organization or any water quality officer.

With the successful deployment of the project, the farmers will be able to achieve higher profits more efficiently which may increase the popularity of crab farming. This will affect the crab industry positively. The presence of crabs in the local market will increase and the price may become more affordable than they are. Moreover, the amount of international demand and export of mud crabs can be increased.

6. Project Goals

The goals of our project are listed and explained below:

- **Decreasing Cannibalism:** The primary objective of the project is to prevent or decrease the cannibalism rate of crabs in pond water farming. In our project, we intend to use the probable acoustic behavior of crabs to detect distress among the crabs. Various crabs produce a sound which is known as rasp/chirp/rap sounds. Ghost crabs, Dungeness crabs, and a few other species are famous for such acoustic displays [4]. Ghost crabs, Dungeness crabs, mangrove crabs such as Perisesarma spp. produce noise when they feel threatened or in presence of an intruder inside their established territory [5]. We intend to use this behavior of the crabs to implement a machine learning system on an IoT device that will detect/identify sounds made by the mud crabs. If the device determines the sound as the sound produced by the crabs when it feels vulnerable, it will dispense food so that any chances of cannibalism due to food shortage do not take place. The system will be able to identify as well as notify the farmer if it finds the sound continuing for a longer period. The system completely relies on the ability of the crabs to produce any sound and noise. Unfortunately, in the context of Bangladesh, though Scylla Serrata and Scylla Ovacea are the most popularly grown species of mud crabs, there is no dedicated research done on them regarding their capability to produce any sound.

- **Ideal Water Quality:** The water monitoring system will ensure the crabs grow in an ideal environment. Water quality is very crucial in crab farming. Crabs are highly responsive to water quality. Water quality can cause the growth rate to decrease as well as change the behavior of the crabs. Water salinity, temperature, pH, DO, NHx level everything is needed to be monitored regularly and accurately. Farmers cannot buy expensive equipment to perform these tests by themselves. They rely on other organizations or water quality officers of various NGOs or agricultural organizations to test the water quality. Though do not have to buy any equipment but they do have to pay money for the tests. Thus, regular water parameter testing and maintenance can become costly and failure to regular testing can cause severe loss as well. The system aims to eliminate this issue by constantly monitoring the water quality. The system will log the parameters and notify the farmer if any of the parameters goes above or below the threshold range.

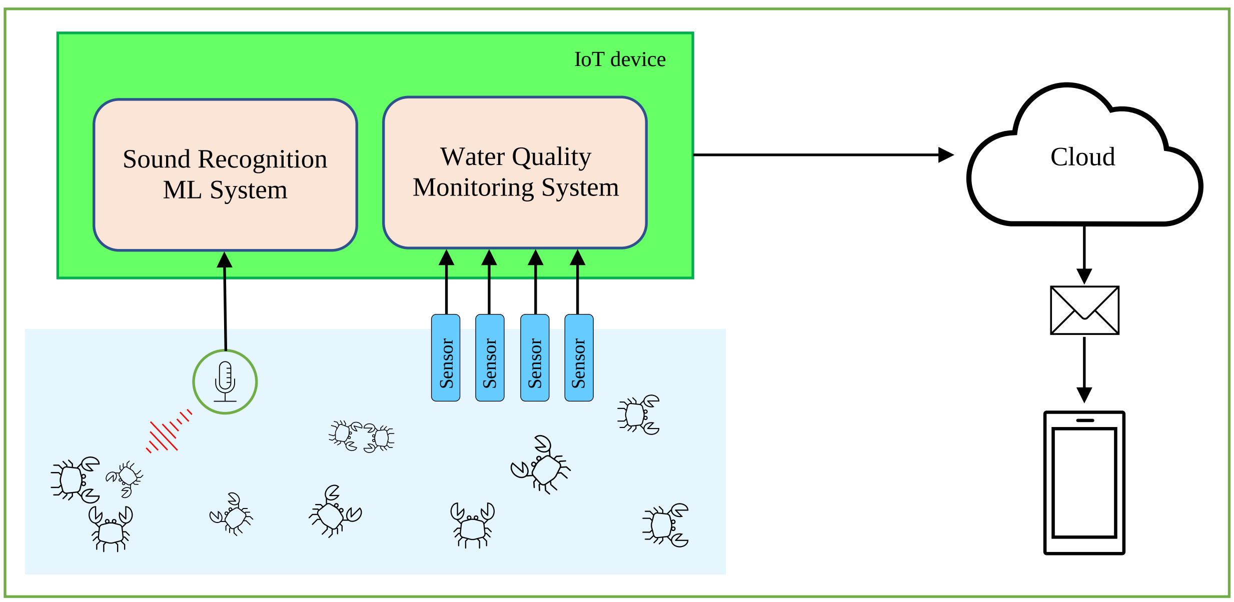

Figure 1: Project Diagram

7. Procedure & Work Allocation

The procedure to achieve the goals are written in steps below:

Step 1: Collecting Sound Samples
Objective: Collect sounds or noises made by crabs by visiting crab farms or crab fatteners
Equipment: Microphone, Sound Recorder
Estimated Time: 3-5 days

Step 2: Data Pre-processing
Objective: Remove noises, resize target sounds to the same length
Equipment: Audio editing software
Estimated Time: 1 day

Step 3: Build and Train the CNN model
Objective: Make a Convolutional Neural Network (CNN) and train the model to classify crab noises
Equipment: Python, TensorFlow, Google Collaboratory, Edge Impulse
Estimated Time: 2 days

Step 4: Hydrophone
Objective: Collect or make your DIY hydrophone as hydrophones are expensive
Equipment: Components Listed in **PDF: Microphones, Hydrophones, Vibration Transducers: Rolling Your Own** by **David Dunn[14].**
Estimated Time: 1 day

Step 5: Water Quality Data
Objective: Collect ideal water quality parameter data from various research as well as from the crab farms and fatteners
Equipment: Online Research paper, documents, crab farming records, etc.
Estimated Time: 2- 3 days

Step 6: Acquiring Necessary Sensors
Objective: Search and acquire necessary sensors that are compatible with IoT devices to measure target water parameters. The sensors can be found in online stores or hardware stores.
Equipment: Necessary sensors compatible with IoT devices
Estimated Time: 2-3 days

Step 7: Programming the IoT device
Objective: Configure and upload the model to an IoT device such as Raspberry Pi or Arduino. The TensorFlow CNN model will be converted to the TensorFlow Lite CNN model. The continuous input from all the sensor and their parameters will be set by programming. The software will be built using language compatible with the IoT device.
Equipment: Programming Languages such as (C, Python), Compiler
Estimated Time: 2-3 days

Step 8: Simulation
Objective: Simulation will be done to analyze and validate if the software and hardware are working as required
Equipment: IoT device Simulation Software
Estimated Time: 3-4 Days

Step 9: Deploying the software in the IoT device
Objective: Deploying the software into the IoT device after successful simulation. The software must be deployed successfully into the device.
Equipment: IoT device, Operating System, necessary software
Estimated Time: 1 day

Step 10: Assembling All Components
Objective: All the sensors and components have to be connected to the IoT device accordingly to their pins declared in the firmware.
Equipment: Sensors, wires, soldering iron, etc.
Estimated Time: 1-2 days

Step 11: Real-life Testing and Tuning
Objective: The complete project will need testing and tuning with real-time data. Crab sounds can be played by the speaker to test the sound recognition system. Water quality sensors can be tested by using water and changing the properties of the water. The testing can be done at home or laboratory easily.
Equipment: Assembled IoT device, speaker, water, etc.
Estimated Time: 2 days

Step 12: Analyzing Effect on Various Aspects
Objective: The project aims to help the farmers by making crab feeding and water quality monitoring efficient and reducing the cannibalism rate to increase profit. But it may have an impact on the economical and social aspects of the farming and farmer as well. Also, effectiveness on the environment must be considered. If any negative impact is to be found, it is a must to find a solution or reduce the impact as much as possible.
Estimated Time: 1 week

7.1 Work Breakdown Structure (WBS)

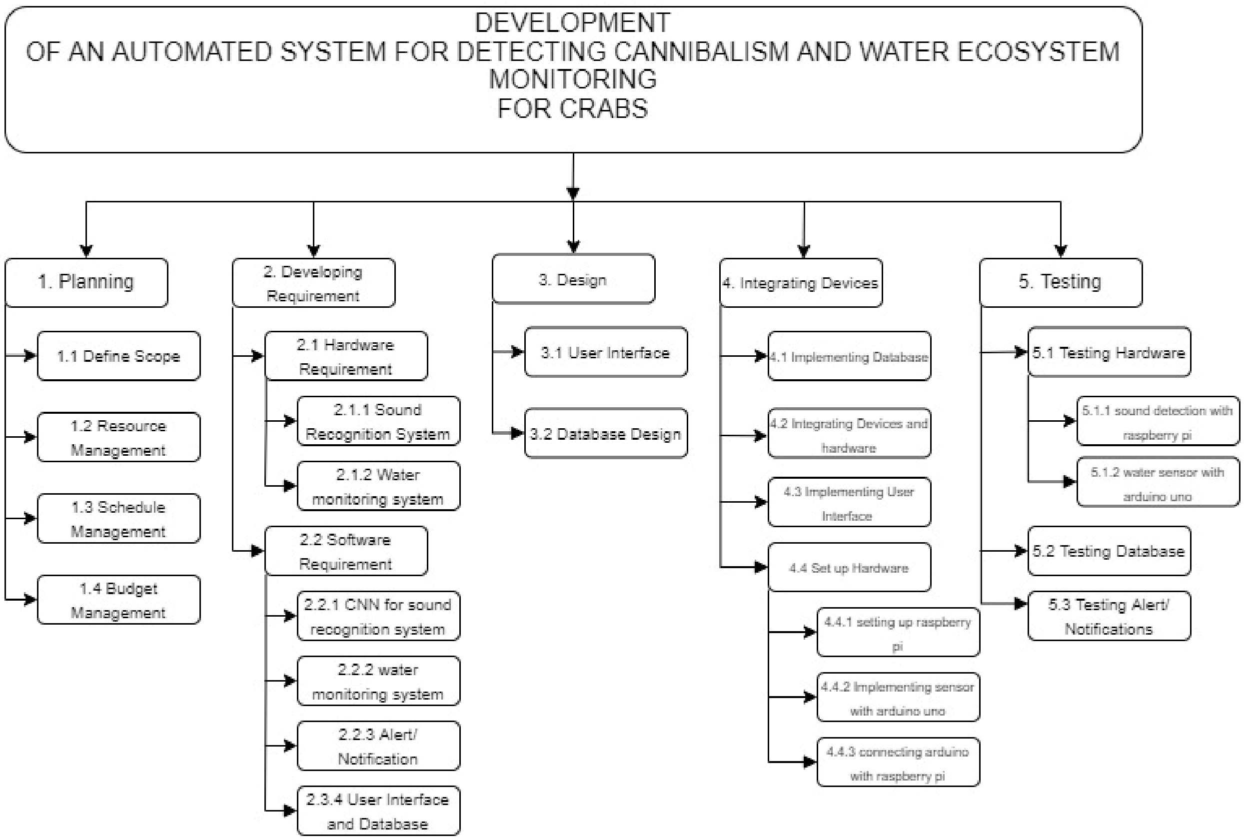

Figure 2: Work Breakdown Structure

7.2 Project Gantt Chart

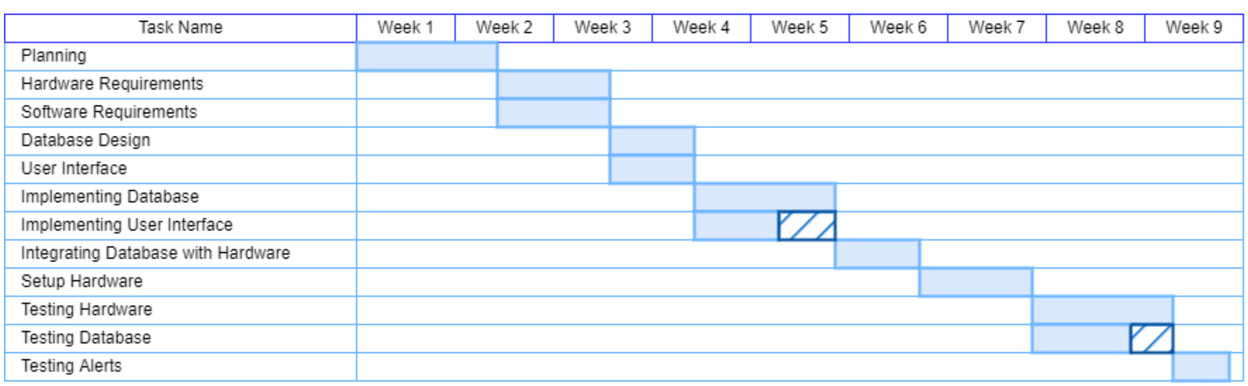

Figure 3: Project Gantt Chart

7.3 Critical Path Method (CPM)

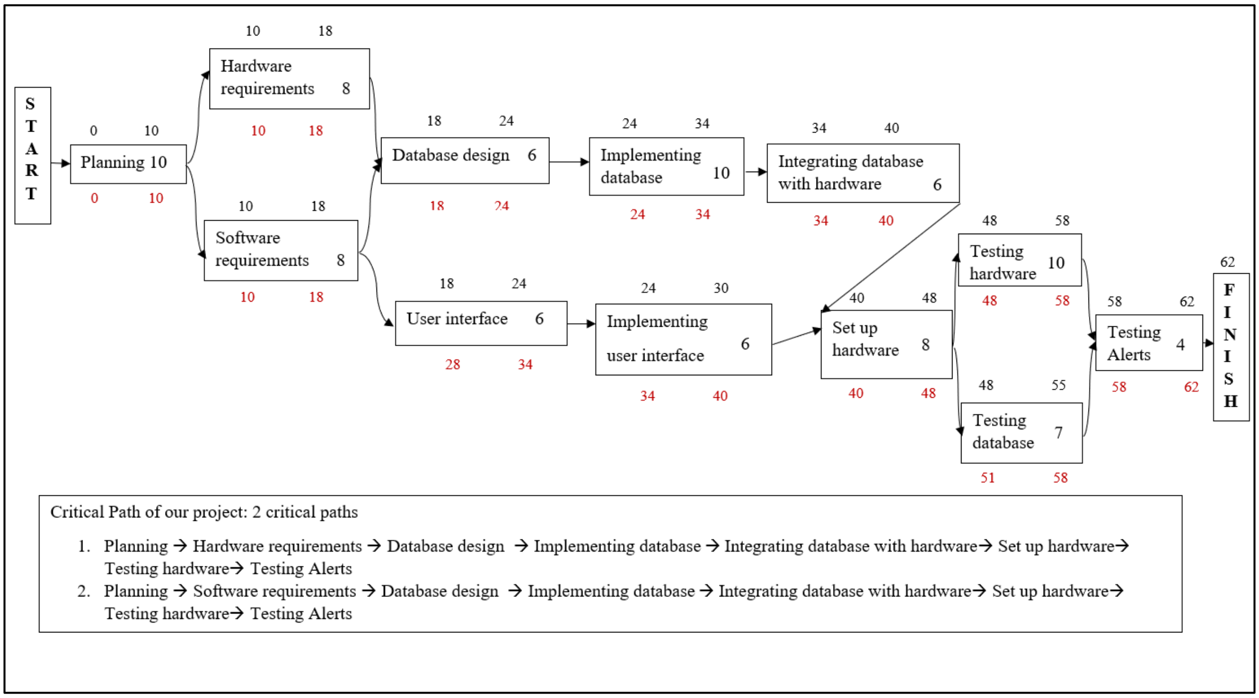

Figure 4: Critical Path Method (CPM)

7.4 Cost Analysis

Task	Duration (Days)	Cost (TK)
Planning	10	80,000
Hardware Requirements	8	26,000
Software Requirements	8	38,000
Database Design	6	37,250
User Interface	6	1,62,500
Implementing Database	10	1,82,500
Implementing User Interface	6	54,000
Integrating Database with Hardware	6	1,15,000
Setup Hardware	8	1,00,000
Testing	14	1,82,000
Total		**9,77,250**

Table 1: Cost Analysis

In Table 1. we estimated the total cost from the production level till the implementation of our device.

8. Materials and Method

8.1 Designing Solution

In our project, we aim to classify crab's sound or noise with a machine learning model and a continuous water quality monitoring system.

We could have analyzed crab feeding behavior with a camera. But the water in which crab lives is not freshwater. So under muddy water, it is very difficult for a camera to capture images or videos of crab's behavior. If we use a highly sensitive night vision camera it is possible to capture those types of images or videos. But it is very costly to implement these kinds of cameras for our project and it is not affordable for the farmers. So, we will not use a camera in our project for analyzing the behavior of crabs.

Crabs such as Atlantic Ghost crab, Dungeness crab, Hermit crab, and various mangrove crabs produce sound when they are annoyed or threatened or when any other crab trespasses their territory. So, when they are about to get cannibalized by another crab they produce noise to scare off the predator. This sound can be captured by hydrophone. Thus, this becomes one of the core elements of our project.

As sound is very crucial for our project, the continuous capture of sound from the pond is necessary. Hydrophones are microphones that can be used to collect acoustic samples or sound under the water. Hydrophones are waterproof and sensitive enough to capture the sounds underwater which are usually impossible to collect or sample and hear. But hydrophones are expensive and usually hard to maintain. So, we took a "Do It Yourself (DIY)" approach to solve the problem. The DIY Hydrophone might not perform as effectively as other expensive hydrophones available on the market but may help to investigate the behavior of crabs when they are hungry.

Water parameters could have been monitored by us using chemical reagents or tools. But chemical reagents test is not a real-time process or continuous process. The test with chemical reagents takes time from a few hours to a day to provide the results. In the case of water quality testing with tools, it can be very expensive, time-consuming, and complected for the farmers. There is no "All in One" tool to test all the water parameters. Different tools have to be bought to measure each parameter. So, buying all sorts of tools will be expensive for the farmers. Moreover, these tools are very sensitive and complicated to use. As farmers are mostly uneducated, they can not operate or maintain such tools. Thus both of the methods are impractical for continuous and real-time water monitoring. In aquaculture, water quality monitoring is very important and farmers need to know the water quality update from time to time.

Nowadays IoT devices are popular for making these types of monitoring systems. IoT devices such as Raspberry Pi, and Arduino support a wide range of sensors that can read temperature, pH, salinity, DO, etc. continuously. These sensors consume little power and do not require any training or knowledge to be used. For crab farming water temperature, pH and salinity play a vital role. So, we intend to use these sensors with IoT devices. This will make reading these water parameters continuously and in real-time very easy and efficient. There will be little to no complexity for the framers to use this system.

8.2 Description of the Proposed System

The feeding system will feed the crab depending on their behavior and time. The feeding system will rely on the sound recognition algorithm. The sound recognition will be done using Convolutional Neural Network(CNN) built with python and TensorFlow. The system will collect sound samples using a DIY hydrophone and determine whether the sound is made by the crabs. In case of a positive occurrence (crabs rasp/rap), the system will start dispensing foods to the crabs. The machine will dispense a measured amount of feed to prevent any chances of overfeeding or underfeeding. The system will stop dispensing food when the right amount of food is dispensed. Upon finishing, the system will notify the farmer about the event via SMS. If the crabs do not produce sound, the feeding system will still dispense food at the feeding time set in the system by the farmer. So, the farmer does not have to keep the system in check if the system fed the crabs or not.

The water monitoring system will ensure the crabs grow in an ideal environment. Water quality is very crucial in crab farming. Crabs are highly responsive to water quality. Water quality can cause the growth rate to decrease as well as change the behavior of the crabs. Water salinity, temperature, pH, DO level everything is needed to be monitored regularly and accurately. Farmers cannot buy expensive equipment to perform these tests by themselves. We will use sensors for temperature, pH, and salinity with IoT devices. The system will log the parameters and notify the farmer by sending an SMS if any of the parameters goes above or below the optimal range.

8.3 Description of the Proposed Components

- **DIY Hydrophone**

As hydrophones are expensive, we decided to make our hydrophone. For this the following components and tools are necessary:

1. Piezoelectric Transducer
2. Plastic Pipe/Acrylic Floor/Small Container
3. O-ring, Glue, and Tape
4. Solder
5. Screw and nuts
6. Plastic-Dip or Epoxy Resin
7. Cable and 3.5mm Headphone jack

Process of assembly: Firstly, we must prepare the container for the components to stay in. The container must be watertight and strong enough to keep the components inside safe from pressure and water. Using a hard PVC pipe, acrylic floor, or a small container can be a wonderful choice. Here, we will use Acrylic Floor. We will cut two equilateral triangles with at least 4 inches per side. Then glue a small rubber O-ring in the exact canter of the triangles. Inside the O-ring, we will have to glue the Piezoelectric Transducer. While gluing the transducer, we must be careful to put the piezoelectric film side upwards. Then, we must cut a hole into the other acrylic triangle. The whole should be within the interior of the O-ring when both triangles are aligned.

Now to assemble, the two triangles must be aligned. The piezoelectric transducer must have wires attached to the two surfaces and the wires will lead through the hole created previously. The three edges need to be taped, better if the transparent tape is used. Now, three holes have to be drilled near the vertices of the triangles. With proper screw and nuts, the assembly should be secured.

We have to solder our long wires to the wires connected to both surfaces. The wires of the cable and from the transducers must be soldered properly. All the soldering and exposed wire must be covered. The other end of the wire needs to be soldered to a 3.5mm audio jack.
The whole assembly has to be dipped into a plastic dip or Epoxy Resin. This may reduce the sensitivity of the hydrophone, but it is a crucial step to make the hydrophone waterproof [16].
The approximate price for making this DIY Hydrophone will be around 1600 Taka.

- **Tools Used**

We used edge impulse for our operations. For pre-processing, characteristics extraction, and making the CNN classifier, we used edge impulse as our tool. The model is also tested on the edge impulse, the accuracy achieved is 86.25%. The accuracy for "Crab Crawl" was 100%. This means due to insufficient data; the model is overfitting. Changing values or layers of the Neural Network did not improve the situation, so it is kept as it is.

- **pH Sensor**

For measuring the pH value of a liquid, a device is used, which is called a pH sensor. The concentration of hydrogen ions in a liquid is defined as pH. By finding the pH value of a liquid, it can be defined whether the fluid is basic, acidic, or neutral [17].

The picture of the pH sensor is shown below.

Figure 5: pH Sensor

- **Temperature Sensor**

For measuring, the temperature which the device is used is called a temperature sensor. This sensor can be used for detecting liquid temperature, the temperature of the air, and solid matter [18].

There are different types of sensors to measure the temperature:

Thermistor: The size of this sensor can be very small. They consist of detection elements coated with glass or epoxy and have two wires to connect to the circuit. The temperature is measured by measuring the change in the resistance of the current. Thermistors are available at either NTC or PTC and are often cheaper [18].

RTD: Resistance temperature detectors known as RTDs, work like a thermistor and measure ohm resistance to measure temperature. They connect to circuits like thermistors, but the range of the temperature is much higher and extreme temperatures can be measured by it [18].

Thermocouple: This sensor uses two conductors made of different metals bonded at the ends to form a joint. When this junction is exposed to heat, it produces a voltage that is directly proportional to the input temperature. These are extremely versatile, as the combination of different metals allows for different measurement ranges. However, due to the lack of precision in NTC and RTD, it is the least accurate of the three types [18].

Temperature Probe: These sensors are quite common and have several types of temperature sensors. They consist of a thermistor, thermocouple, or RTD sensing element and can be fitted to a contact head. All three types of sensors can be manufactured with different types of housings (standard and custom). It provides extended utility to cover the various environments and media they encounter [18].

For the simulation purpose, we used a temperature sensor in the Proteus software which is LM35. LM35 is an RTD type of temperature sensor.

The picture of the LM35 temperature sensor is shown below.

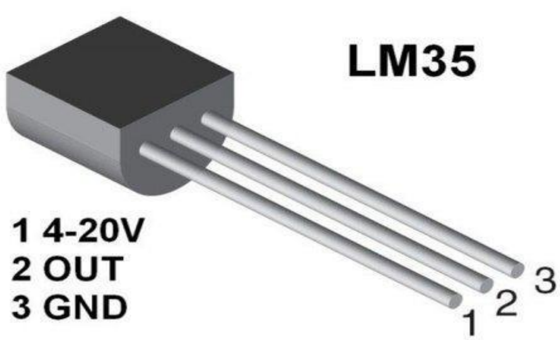

Figure 6: LM35 temperature sensor

Using the analog port, the program below simply reads a value from the LM35. It then outputs the Celsius and Fahrenheit temperatures to the serial monitor window.

We used Arduino for our simulation. So, the parameters in the sensor equation are used as they should be in an Arduino program. We used the float voltage of the pin as raw temperature. Now the equation stands as such, (raw temp * 5.0 / 1024) * 100

The equation converts the LM35 output to Celsius. This line simply takes the raw analog value and multiplies it by 5.0 because the Arduino circuit reference voltage is 5V. Next, the Arduino has a 10-bit Arduino circuit that provides 1024 resolution steps, so this number is divided by 1024. The result of this calculation gives the voltage measured across the LM35 (range 0-1.5V). The output of the LM35 is 0.010V per degree, so multiply this number by 100 to move from voltage to temperature in degrees Celsius [19].

8.4 Simulated Our Proposed Model

- **Simulation of Machine Learning Model and Sound**

The machine learning model will be used in an IoT device to be implemented in a real environment. Therefore, it is necessary to test the model. Without any hardware, the best way to understand and analyze the model is to simulate the model in virtual hardware.
As our simulation tool, we used proteus. Software to simulate various electrical components and circuits.
In the simulation, the first challenge was to get an IoT device library, then to get continuous input from the microphone and simulate an output from the model for the input sounds. As proteus has a vast community we were able to find an Arduino UNO library. Unfortunately, the model we created cannot be implemented in the Arduino UNO. The Arduino UNO library we found was not enough to simulate the model. The proper hardware for our model seemed to be Arduino Nano 33 BLE Sense. But we were able to simulate the continuous input and the model separately.
The continuous input from the microphone was simulated in the proteus.

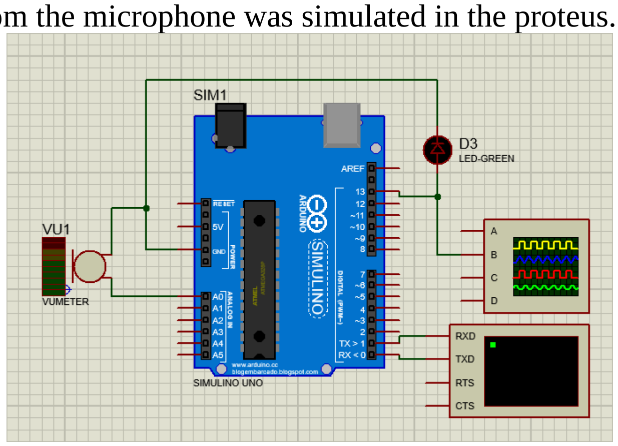

Figure 7: The Schematic Capture for the continuous microphone input

In the Schematic we can see the Arduino UNO. With its Analogue input pin A0, A VU METER is connected. VU METER is a device library provided by proteus that takes input from the computer's microphone. Another end of the VU METER is sharing the ground node of the Arduino

UNO with a green LED. The green LED's other end relates to the digital pin 13 of the IoT device. We connected an Oscilloscope and a virtual terminal to the circuit to view the outputs. When we generated a sound greater than provided threshold the LED lights up.

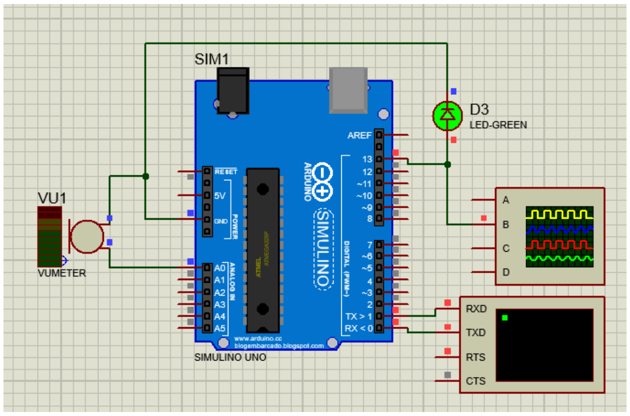

Figure 8: The LED turns green when the sound exceeds the threshold

The Audio recognition CNN model is tested over the edge impulse desktop and mobile deployment. The simulation results were satisfactory. The simulation was not done on the edge impulse as there was no library to run machine learning simulation in proteus or other simulators. Various other simulation platforms such as MATLAB's Simulink require hardware to be connected to the computer to run a simulation. For the lack of hardware, the CNN model was only tested via computer and a smartphone.

- **Simulation pH and Temperature**

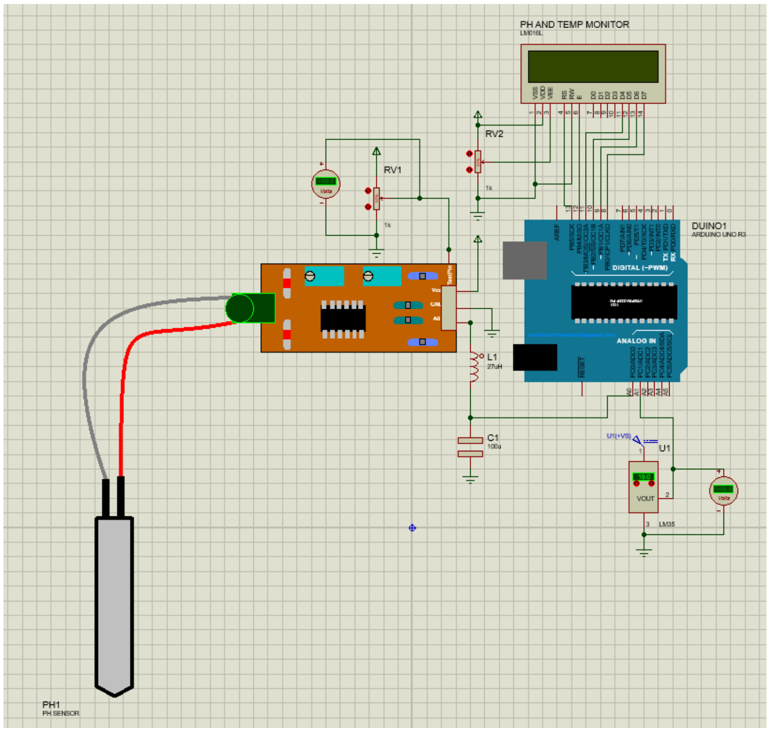

Figure 9: Circuit Design

Design components: Arduino Uno board, Capacitor, Inductor, LM016L Display, LM35 Temperature Sensor, pH Sensor, and POT-HG Potentiometer.

- **Audio Recognition with Machine Learning Model**

The accuracy of the model is not 100% or anywhere close but the result is quite satisfactory. The Model can detect Crab Grawl or Rapping sound correctly most of the time.

0.99	0.01
1.00	0.00
0.00	1.00
1.00	0.00
0.12	0.88
0.44	0.56
1.00	0.00
0.99	0.01
0.51	0.49

Figure 10: The model outputs values close to 1 when Crab Rapping sound is played over the microphone

1.00	0.00
1.00	0.00
1.00	0.00
1.00	0.00
1.00	0.00
1.00	0.00
1.00	0.00
1.00	0.00

Figure 11: The model outputs values close to 1 when an Unknown sound detected

The accuracy of the model can be improved. In the future, more sample audio data of crab rapping can be collected which will help the data scarcity as well as improve the performance of the model.

The sufficiency of the sample data can help to prevent overfitting. With so much insufficiency of data, the performance of the model is acceptable.
As sound can be continuously detected and the model can classify the crab rapping with more than 80% accuracy, the feeding system can be built now. The system can act such as notifying the farmer that crabs are hungry and starting the automated feeding process. With this, the crabs will have to wait less and can be fed efficiently. This may become a great feeding solution for the fast-growing crab farming industry.

- **pH and Temperature Result**

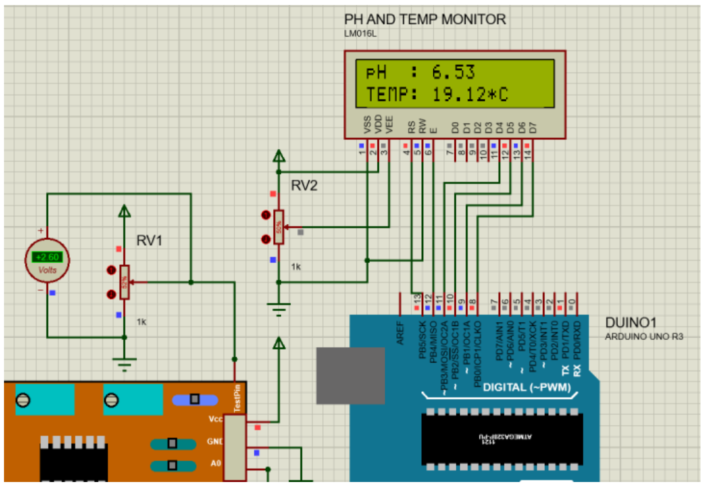

Figure 12: Measuring the pH and Temperature Value

Update the result when we change the voltage manually.

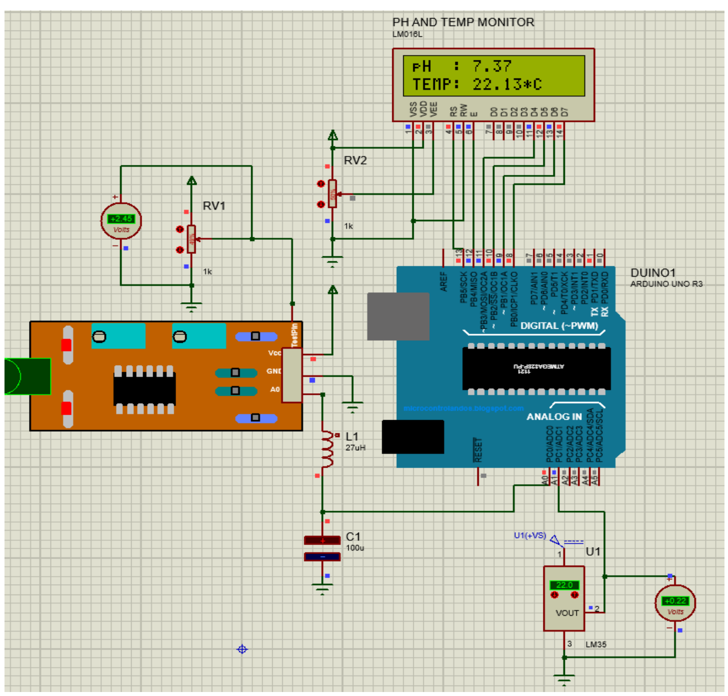

Figure 13: Changing the pH and Temperature Value

- **Discussion of the Simulation Result**

The design circuit is working as intended and the circuit model returns the correct value.
Now calculate the value via this formula:

For pH sensor:
Using the equation for the temperature sensor

$$y = -5.70x + 21.34$$

$x = +2.45$ (We put this voltage in via a potentiometer)
Our main voltage is **5V**. So, **49%** of **5V** is = **2.45V**

$$y = -5.7 * 2.45 + 21.34$$

$y = 7.375$, which is our pH value.
From the above calculation, our pH meter return value is the same.
So, our model works correctly to measure pH.

For the Temperature sensor:
From the formula for the temperature sensor. we know, that the output of the LM35 is 0.010V per degree.
We measure the voltage as **+0.22V** with a voltmeter.
The final temperature = $0.22V/0.010V = \mathbf{22°C}$
We can see that the calculated value is almost the same as the temperature meter. So, our model works correctly to measure Temperature.

We know for the crab culture, the water pH should be 5 to 9 and with this sensor, we can measure pH on a scale of 0 to 14, which is the full range of the pH scale.
The temperature of the water should be 21℃ to 35℃ and we can measure temperature in a range of -55℃ to 150℃ with this sensor.
Water salinity is the most important for crab farming. The preferred salinity scale for crabs is 15-25 ppt. By monitoring water salinity, it is easy to control. Besides salinity dissolved oxygen is also a crucial factor for crabs farming because oxygen is a vital part of metabolism. Dissolved oxygen can control the label of ammonia. High-label ammonia in water is not good for crab farming because it stopped the crab's cells from increasing. The dissolved oxygen should be 4-5 ppm for crab farming. Like pH and temperature, we can measure water salinity and dissolved oxygen with a sensor, and we can control them easily.

8.5 Materials

1. **Raspberry Pi:** Raspberry pi is a small single-board computer and it will act as a mini personal computer. It is widely used for real-time data processing and IoT-based applications. It can run various Linux-based operating systems like Ubuntu, Archlinux, Raspbian OS, etc. In our implementation, we used Raspberry Pi 3 Model B+ which is capable to run a machine learning model. It has a 1.4GHz 64-bit quad-core processor, dual-band wireless LAN, Bluetooth 4.2/BLE, etc. which are crucial for our project. Raspberry pi can run a local server which is very helpful to create a globally accessible interface. In our case, we used NGINX and PHP to create the local server and the interface.
2. **Arduino Uno:** The Arduino UNO is a microcontroller board that can be unified into a variety of electronics projects. It is also an affordable and flexible device and also the first USB board that is released by Arduino. It includes 6 analog input pins, a USB connector, 14 digital pins, and a power jack. It is programmed based on the IDE. In our project, we used this for reading the data of our sensors and sending those data to the Raspberry pi.
3. **Hydrophone:** A hydrophone is a device that is used for detects underwater sound detections and record sound in all directions. We made our hydrophone with the Do it Yourself (DIY) process.
4. **Water Sensors:** We used pH, Temperature, Salinity, and BOD Sensors for our work.

8.6 Data Collection

Crab behavior analysis and their behavioral relation with sound are quite unexplored. As a result, audio or sounds generated by crabs is very scarce over the internet. Though there are a few audio files named or categorized as "Crab Sound" most of them are artificially generated audio for various production use in other audios, games, or other contents. We managed to find an audio file where crabs produced rapping sounds.
We collected necessary data such as optimal water parameters or crucial water parameter thresholds which are available in the references 20, 21, and 22.

8.7 Data Sampling

The audio file length is about 20 seconds, but it has almost 14 individual raps. Using the Audacity software, we created about 32 samples of 1-second length with variations among them. The variation is created by increasing the decibel level of the sounds, different starting times, and panning audio output to left or right. The step is done to increase the number of samples and to make each sample different from the other. Only 32 samples are not sufficient for the best result, but it is still satisfying as the data is so rare.

8.8 Design/Framework

For our machine learning, we implemented a Convolutional Neural Network (CNN) classifier model. The CNN has layers of virtual "neurons" that filter and transform the input (in our case it is the MFE Spectrogram) depending on the state of the neurons are in. The output of the first layer is an input of the second layer, and it goes on until the output layers. Finally, as output, we receive the probabilities of each class.

In our Neural Network, we have an input layer that takes 3,960 features as input. In the first layer, we used a Conv1D layer. As we have time-series data, con1d is the best suited. Then the

MaxPooling1D downsamples the inputs. This helps the neural network to identify where features were supposed to be instead of their exact location. It also saves some computation in the next layer. The dropout is added to prevent overfitting as much as possible.

Another level of the same structure is again added except the kernel and filter sizes are different than the previous layer. To convert feature data into a one-dimensional vector, a flattening layer is used. The flattened vector is then fed to a neural network in the Dense layer. We only used four neural networks which are equal to our number of classes. The learning rate of the CNN model is set to 0.005. This seemed to give the best result. Epochs are set to 100 to get the best weights possible.

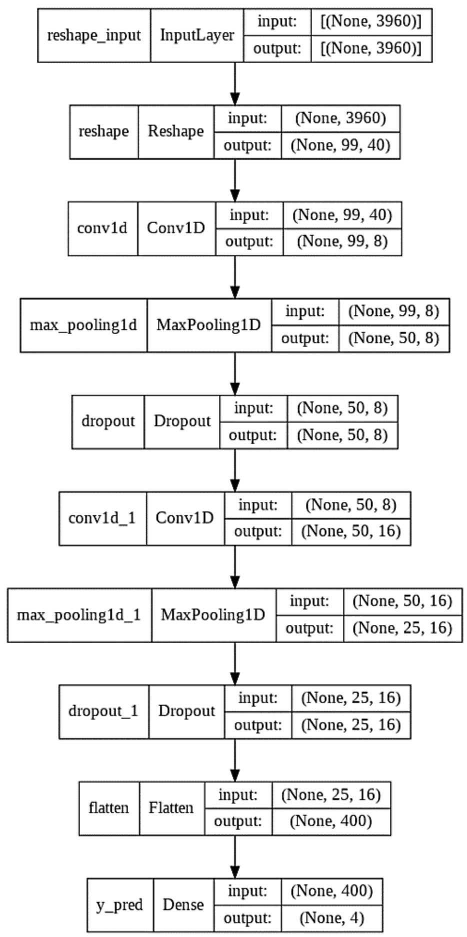

Figure 14: Plot of the implemented Convolutional Neural Network Classifier

8.9 Algorithm

- **Audio Recognition Principle**

Audio recognition is pattern recognition. It only requires some function modules for audio like characteristic extraction, characteristic modeling, audio signal pre-processing, pattern matching, etc. [24].
The structure can be shown as such:

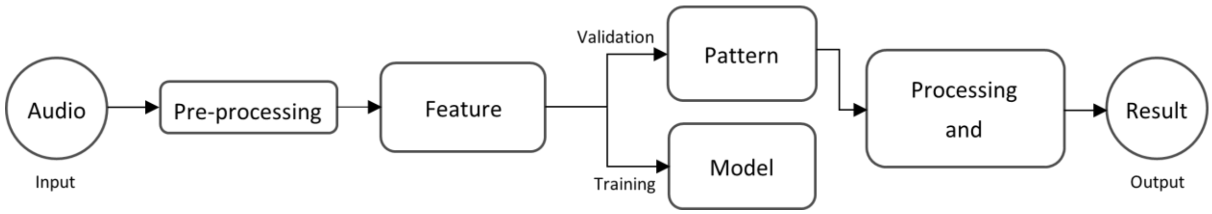

Figure 15: Audio Recognition Block Diagram

- **Pre-processing of the Audio**

It is necessary to pre-process the audio signals before using them to train and validate a Convolutional Neural Network (CNN) model. In pre-processing there are steps such as filtering, Analogue to Digital conversion, pre-emphasis, frame, endpoint detection, etc. Let, X(n) a digital signal that is an output of A/D conversion. The processing process is as follows:

1. The Normalization Process is used to control the sample fluctuation in the range [-1, +1] and remove the difference between different audio samples [24].

2. Pre-emphasis is usually finished using a digital filter with 6dB/Octave, just shown in the following formula. The μ in the formula is a constant which is usually 0.97 [24].

$$H(z)=1-\mu z^{-1}$$

3. Window-framing controls the length of sample collection duration, in milliseconds. This eliminates variation in the length of the sample data. For our approach, we took one second or 1000 milliseconds for the window. Each window will start after 500 milliseconds or 0.5 seconds after the previous window.

- **Feature Extraction:**

To extract features or characteristics of the audio we used the Mel-filterbank Energy (MFE) feature. MFE transforms a window of audio into a table of data [9]. Each row in the table stands for a range of frequencies and each column represents a period. A spectrogram can be generated from the data table. In the spectrogram, each cell is colored where the intensity of the color depends on the amplitude [25].

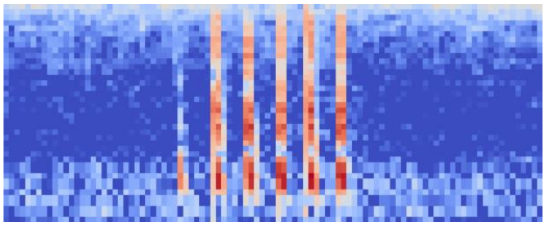

Figure 16: Spectrogram of **"crab growl"** sample

The difference between the two sounds is visible in the spectrogram. Similarly, for each category or class of audio, the feature generates different spectrogram images where audios of the same class have spectrograms that are close to each other.

8.10 Experiment Setup

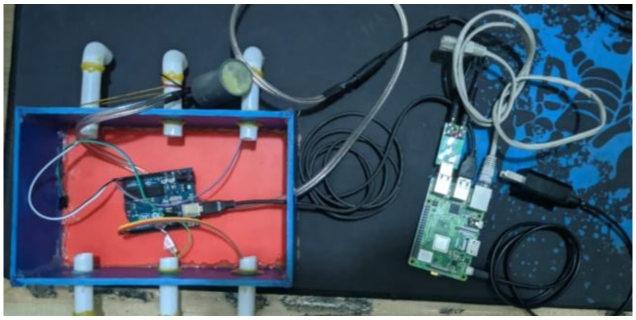

Figure 17: Device connected (with sensor compartment)

We connected our water sensors with Aurdino Uno then we connected it with raspberry pi. Sensors data are passed with Arduino UNO to the raspberry pi. Then we implanted our machine learning model in Raspberry Pi and got our result from the Raspberry Pi server through email.

8.11 Math Formulation

- **Calculating the pH Value of a Liquid with the pH Sensor**

As the sensor is linear, we have to take two points and assume the equation to convert the measured voltage pH. The general formula should be $y = mx + b$. Where m and b were pre-calculated. M is the slope and b is the y-intercept. The x is the voltage and y is the pH value [26].

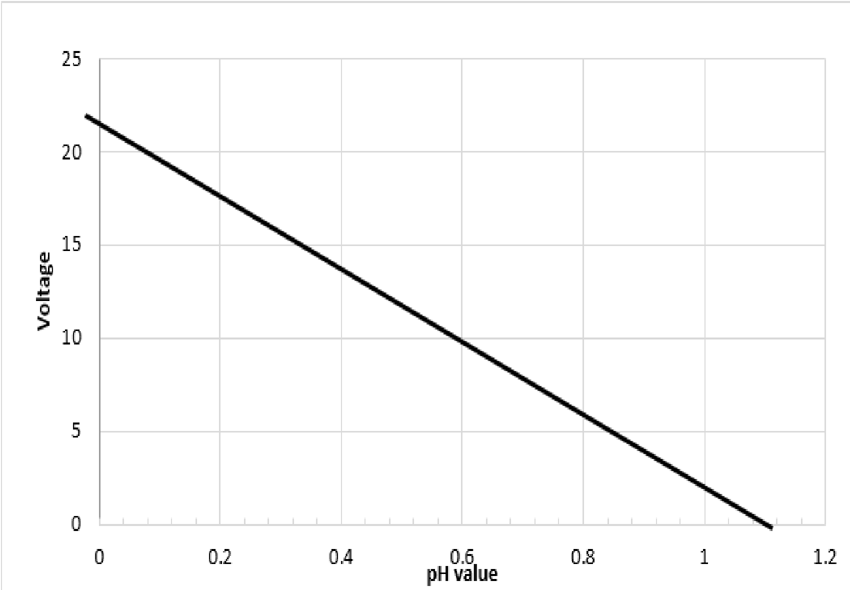

Figure 18: Graph for slope

The slope equation is such,

$$m = (y2 - y1)/(x2 - x1\ )$$

m and b pre-calculated values are -5.70 and 21.34.
So, the result is $y\ =\ -5.70x\ +\ 21.34$

The code takes 10 samples of analog input, sorts them, discards the highest and lowest values, converts this value to a variable pHVol voltage, and calculates the average of the remaining samples. Then use the calculated formula as follows: The pH reference value converts pHVol to pH Value, sends it to the serial port, and displays it on the serial monitor [26].

- **Calculating the Temperature of a Liquid with the Temperature Sensor**

To calculate the temperature the equation is,

$$\left(\frac{raw\_input\ \times reference\ voltage}{device\ resolution\ steps}\right) \times constant$$

In the above equation, raw input is the reading from the sensor. The reference voltage is the operating voltage. Device resolution steps are used to map input voltage and operating voltage within a threshold. The constant depends on the sensor's voltage output per degree.

- **Calculating the Salinity of a Liquid with the Salinity Sensor**

The Vernier Salinity Sensor measures the ability of a solution to conduct an electric current between two electrodes. In solution, the current flows by ion transport. Therefore, an increasing concentration of ions in the solution will result in higher conductivity values. The Salinity sensor is measuring conductance, defined as the reciprocal of resistance. When resistance is measured in ohms, conductance is measured using the SI unit, siemens (formerly known as a mho). Since the siemens is a very large unit, aqueous samples are commonly measured in microsiemens, or µS. Even though the Salinity Sensor is measuring conductance. We are interested in finding the conductivity of a solution. Conductivity, C, is found using the following formula:

$$C = G.k_c$$

Where G is the conductance, and k_c is the cell constant. The cell constant is determined for a probe using

$$k_c = d/A$$

Where d is the distance between the two electrodes, and A is the area of the electrode surface.

The conductivity value is found by multiplying conductance and the cell constant. A potential difference is applied to the two probe electrodes in the Salinity Sensor. The resulting current is proportional to the conductivity of the solution. This current is converted into a voltage[27].

9. Result and Discussion
9.1 Obtained Result

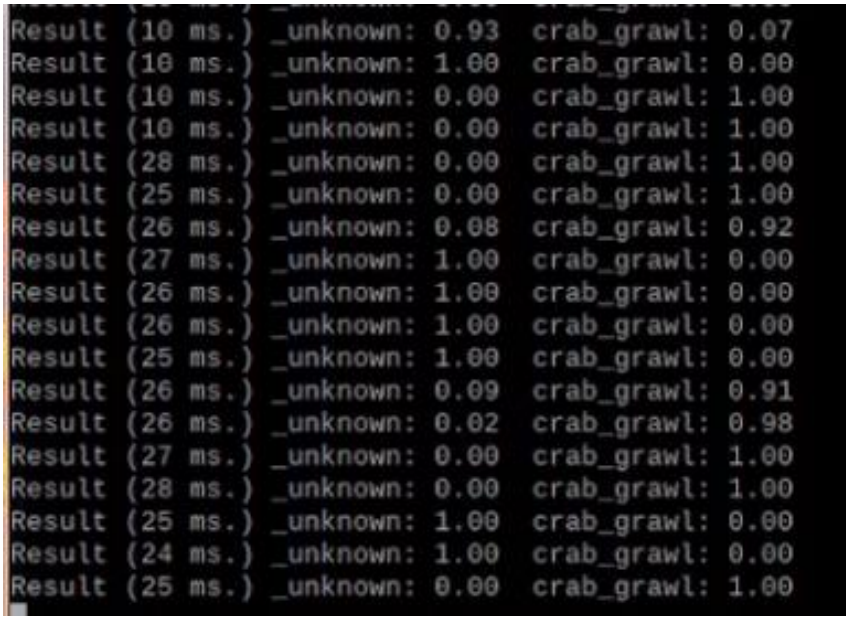

Figure 19: Crab Grawl Detect

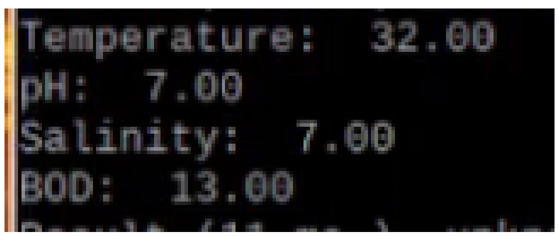

Figure 20: Reading sensor data from Arduino

Our sound recognition model recognizes crab grawl successfully. Upon continuous detection of crab sound, the system writes the event data in the database and sends an email to the end-user to notify. The system reads water parameters every 3 minutes and can notify the user in case of any out-of-range parameter.

Figure 21: Email being sent after detection of crab sound

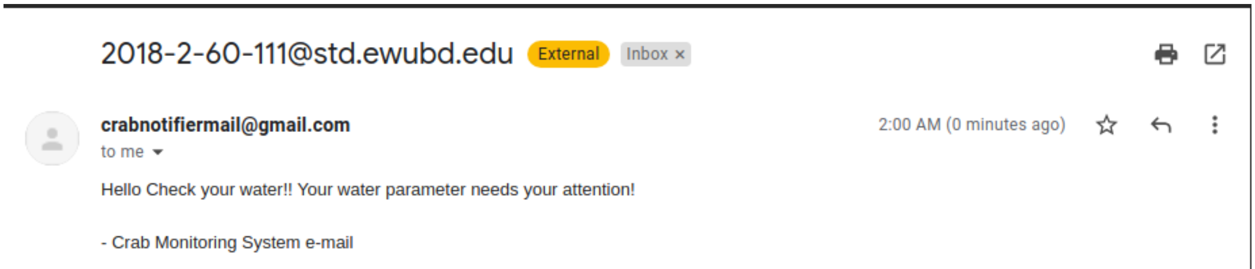

Figure 22: Email being sent after detection of Water parameters

The user can connect to the raspberry pi's local server and view necessary information. The user can view the system status of both the sound recognition system and the water monitoring system.

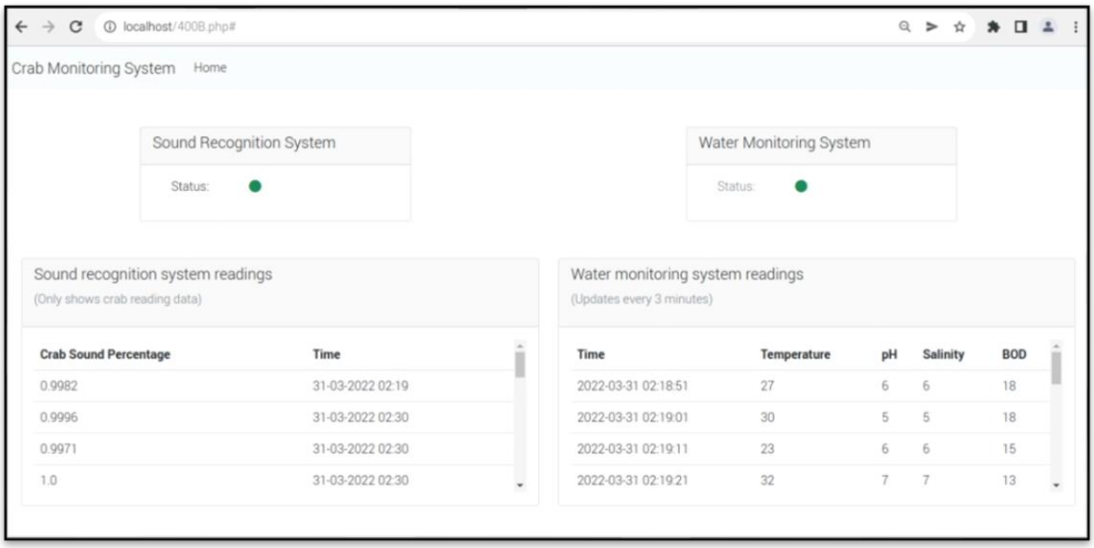

Figure 23: User Interface of Crab Monitoring System

Access to the crab monitoring system via mobile phone connected to the same network as the raspberry pi.

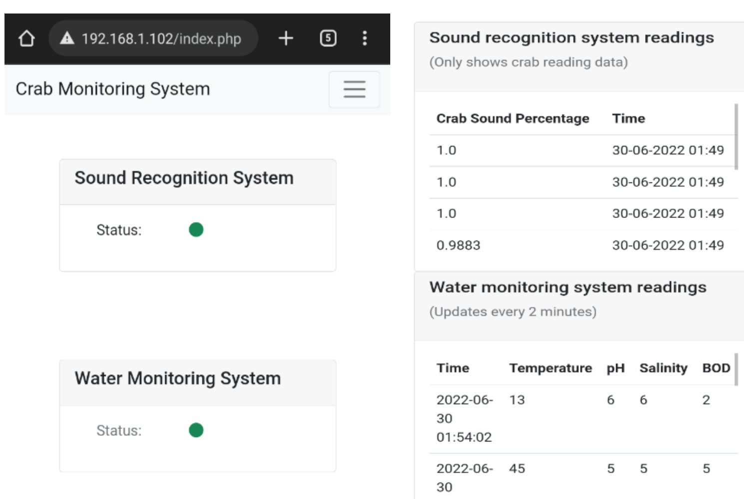

Figure 24: Access to the crab monitoring system on a mobile phone

9.2 In-dept Result Analysis

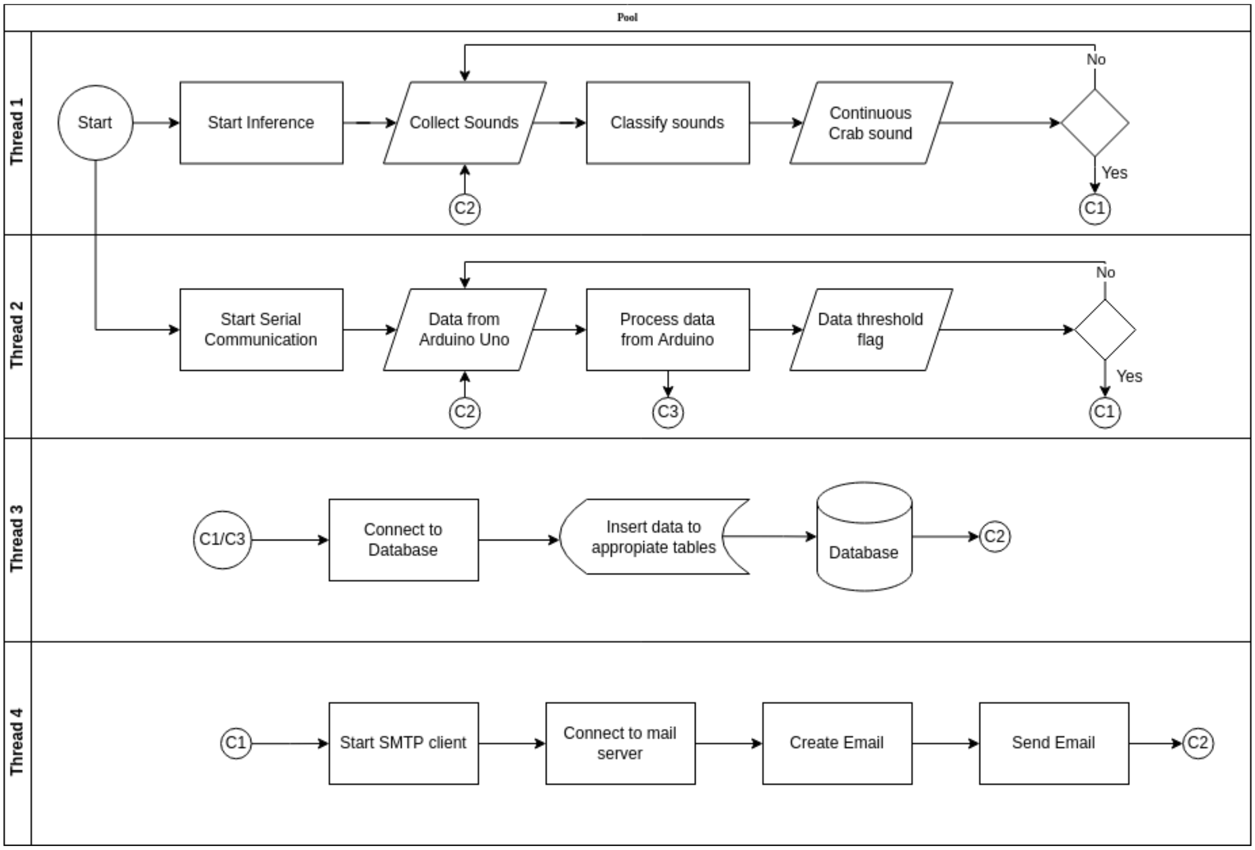

Figure 25: Work Flow Diagram

From our workflow diagram, we get the complete picture of the working procedure of our project. From the diagram, we can see that our project has four threads in total. In the first thread, we start the interface with the Raspberry Pi and collect sound data. Meanwhile, in the second thread, we start Arduino UNO and collect the water parameter data and process them. At the same time in our third thread, we connect the database and insert data into appropriate tables. At last in our final thread start the SMTP client and connect to the mail server. And then SMTP client creates and sends mail to the user when the threshold data is passed.

9.3 Discussion

The accuracy of the sound recognition model can be improved. In the future, more sample audio data of crab rapping can be collected which will help the data scarcity as well as improve the performance of the model. The sufficiency of the sample data can help to prevent overfitting. With so much insufficiency of data, the performance of the model is acceptable. As sound can be continuously detected and the model can classify the crab rapping with more than 80% accuracy.

We know for the crab culture, the water pH should be 5 to 9 and with this sensor, we can measure pH on a scale of 0 to 14, which is the full range of the pH scale. The temperature of the water should be 21℃ to 35℃ and we can measure temperature in a range of −55℃ to 150℃ with this sensor. Water salinity is the most important for crab farming. The preferred salinity scale for crabs is 15-25 ppt. By monitoring water salinity, it is easy to control. Besides salinity dissolved oxygen is also a crucial factor for crabs farming because oxygen is a vital part of metabolism. Dissolved oxygen can control the label of ammonia. High-label ammonia in water is not good for crab farming because it stopped the crab's cells from increasing. The dissolved oxygen should be 4-5 ppm for crab farming. Like pH and temperature, we can measure water salinity and dissolved oxygen with a sensor, and we can control them easily.

10. Research Ethics

For our research, we have taken the lives of the crabs and farmers into consideration. Our implementation is to help the farmers to reduce the cannibalism of the crabs and increase the ability to control the water parameters or take measures to prevent any negative event.

For data collection, we used the online resource Discovery of Sound in the Sea (DOSIT)[23]. The website is developed by the University of Rhode Island's (URI) Graduate School of Oceanography (GSO) in partnership with Inspire Environmental of Newport, RI. The website and its resources were developed and produced with funding from the U.S. Office of Naval Research, U.S. National Science Foundation, U.S. National Oceanic and Atmospheric Administration, the E&P Sound & Marine Life Joint Industry Programme, and the International Association of Geophysical Contractors. Other reputed contributors.

The scientific journals and articles are all collected through legal and free mediums. ResearchGate, Google Scholar, and such publicly available research are used as our reference and related works.

Our implemented devices do not collect any other data than what is strictly necessary. Also, there is no sensitive data stored or handled other than the sounds. Sound is collected, processed, and tested in real-time and not stored. So, there is no possibility of sensitive data being lost or stolen from our implementation.

11. Research Impact on Environment and Sustainability

Research impact is a discussion of how research can benefit or how much it can contribute towards the benefit. It can also contain discussions about the negative impacts of the research. The impact of our findings and implementations on societal, health, safety, legal and cultural aspects is as follows:

- **Socio-economic Impact**

The societal impact of our implementation can be highly positive. Crab farmers have to spend hours feeding the crabs. They must prepare and feed the crabs on time. Also checking the water quality is not easy. Implementation of our findings can be beneficial and efficient for the farmers. The crab farmers will not have to spend the majority of their time feeding the crabs and monitoring the water quality. Instead, as both systems can be automated by our implementation, the farmers will have more time in hand to get involved in more work. This eventually can benefit their socio-economy status. Also, the equipment will be a one-time purchase. As a result, the farmers may not

need to buy expensive and complex tools or utilities. However, the importance of a Water Quality Monitoring Officer or professional may decrease significantly.
The project can also become a way to increase employment within the country. The project can be redesigned as a more compact and modular product. For example, the IoT device can be redesigned and manufactured into an electronic device and the sensors can also be manufactured in a factory. Thus, a new factory can be created that will manufacture the products and the complete project as well. Moreover, there will be more people who will be involved in the process of deployment, maintenance, and repair of the project at the field level. This means more employment will be created which can be beneficial for the socio-economy.

- **Impact on Health**

The health aspect of our implementation can be beneficial for health. None of our used components contain any toxic elements. Moreover, the sensors for water monitoring can help eliminate toxicity generation in the water. The farmers can take necessary steps early in time to control the water parameters that are best for the crabs. Healthy crabs can become a great source of protein and calories. A 1-cup of crab meat has 21g of protein and 97g of calories but contains less than a gram of fat. Crabmeat is rich in vitamin B-12, Folate, Iron, Zinc, and other highly nutritious elements. These nutrition contents make crab meat an excellent replacement for other meats [8]. The audio recognition system can be paired with a feeder to make sure feeding time and the amount is right for each crab. This will yield a better and healthier harvest. Thus, a healthier diet for the consumers as well.

- **Impact on Environment**

The project uses various electronic components. Such as the IoT device, various sensors, and hydrophones. As electronic components do not last for eternity, the hardware used in our project will be no exception. When the hardware components are broken or not functional, they become e-waste. Thus, the hardware in our project will become e-waste when they break. All the components of the hardware contain various metals and plastics which can be harmful to the environment. Direct exposure to these elements or plastics can become harmful to the environment. The e-waste or the broken hardware will have to be handled like other e-wastes. However, the project will not generate too much e-waste as the components are modular and can be replaced; there will be no necessity to replace the complete project hardware when any one or two components break.

- **Safety Aspect**

The project has no element that can cause an extreme safety hazard to a person, crab/fisheries, or the environment around it. The project is made of various electronic components. The IoT device, sensors everything will be operated using electricity. Any malfunction of components may cause a short circuit which can destroy all the hardware completely or any leakage of current can be possible as well. In the first case, there is a lowers chance of any short circuit. As all the components like the IoT device and sensors are mostly printed circuits, any accidental connection is less likely to happen. Even if the connection of the IoT device with the sensors and hydrophone will be established by the connection pins or USB, there are absolutely no chances of such a scenario occurring. On the other hand, in the second case, leakage of current can be possible. For example, the sensors will have electricity passing through them. Any exposed wire or sensor component can leak electricity. However, the IoT device, sensors, and the hydrophone mostly operate at 5V which is not lethal for any person as well as any crab. A human can survive up to 100-250 volts, though there is a case of death at 42volts [9]. The 5V is significantly small and there is no chance of hazard to humans. Similarly for the crabs, there is no chance of any harm. To kill a crab, 220V of electricity is required [10]. This means the leakage of any components to the crabs will cause no harm to the crabs.

- **Legal Aspect**

There is no legal downside related to the implementations is found. The implementation is dependent on the crab farmer/fattener's choice. There is no legal aspect that is concerning to it. But the methods and principles used in this project can be misused. E.g. someone can make a bug or sound capturing device to spy on someone or create an ML model that can detect someone's voice and mimicit.

- **Cultural Aspect**

Lastly, as for the cultural aspect, the impact can take as highly positive. The implementations may become a key aspect to change or revolutionize traditional crab farming. Modernization of the farming, feeding, and monitoring processes may occur. Increased efficiency and profitability may increase the popularity of crab farming and help contribute crab farming contributes more to the economy along with other fisheries.

12. Conclusion

The audio recognition model can be improved in the future by collecting more samples. The overall performance of the model now must be accepted as there were only 32 sample data given to the model to train. The hardware implementation of the model may perform differently as the output of all sensors is not supposed to be the same. In the case of the water monitoring system, we perfectly simulated our design and got accurate results. So, our circuit model is ready for implementation.

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14. Appendix

CO	CO Description	K	EP
CO1	Integrate new and previously acquired knowledge for identifying a real-life complex engineering problem as the capstone project	**K1:** Cannibalistic behavior of crabs, lack of monitoring system for crabs **K2:** Rate of cannibalism in crab fattening in ponds, Effect of water parameters on crabs **K3:** We combined modern technology with traditional crab farming **K4:** i. We had previous knowledge of aquafarming ii. We had knowledge of IoT application in aquaculture	**EP1:** We had knowledge about aquaculture and learned new things about it by reading the aquaculture books and journals. **EP2:** Crab behavior analysis with sound or camera. Water monitoring using a sensor or chemical reagents Underwater sound capturing **EP3:** No other solution is as appropriate as cannibalism detection using the crab sound **EP4:** i. Cannibalism of crabs is still not completely understandable ii. Tolerance of anomaly in water parameters can differ depending on species **EP5:** Engineering ethics such as i. Fidelity ii. Responsibility iii. Accountability Can be achieved. **EP6:** Crab farmers and fatteners are the primary stakeholders, and crab importers/exporters, sellers, and customers are the secondary stakeholders **EP7:** We cannot implement our solution on any IoT device.
CO2	Examine various problem domains (literature review), define the problems,	**K8:** We reviewed various scientific research journals or articles related to our objectives for the capstone project.	**EP1:** We reviewed papers to gain an understanding of crab aquaculture, socio-economical effect, sound recognition, the effect of water parameters, etc.

	and formulate the objectives for the capstone project		**EP2:** There are behavior analysis of different species of crabs, and cannibalistic behavior researches are scarce **EP3:** Most the behavior analysis do not include machine learning or uses image recognition **EP4:** Not all research articles are appropriate for our project, and not all appropriate research is available publicly **EP5:** None of the research was taken without permission or pirated source **EP6:** Authors of the research journals and articles **EP7:** Data or references are not provided directly
CO3	Analyze various aspects of the objectives for designing a solution for the capstone project.	**K1:** Crab behavior analysis, water ecosystem of crabs **K2:** Capture of water parameters and ecosystem of crabs; Capture of underwater sound data using hydrophone; Collection of Data **K3:** i. We used the internet for communication ii. We used solar energy for powering our device iii. Several sensors are used to read the water parameters iv. We developed our own firmware. **K4:** i. We have knowledge about classification to classify different sounds.	**EP1:** We have learned about crab behavior and their analysis from reputed journals. We have learned about water parameters and their effects on crabs from various papers. **EP2:** Crab behavior analysis with sound or camera. Water monitoring using a sensor or chemical reagents Underwater sound capturing **EP3:** i. Capture of suitable water parameters and analysis **EP6:** Crab Framers, Researcher, Scientist, Businessmen, Government **EP7:** i. One is a sound capture and process module

		ii. We have knowledge of collecting physical data using sensors and processing them.	ii. One is water parameter capture and process module iii. To bind everything, we used a software module
CO4	Solutions for the capstone the project that meets public health and safety, cultural, societal, and environmental considerations.	**K5:** i. Continuous monitoring of water parameters for crabs can be beneficial for crab health. ii. There is a possibility of abuse of this system.	**EP1:** We have knowledge about the sensors and devices and tools we used. **EP2:** i. Device can be cooled, and power can be regulated to prevent accidents. ii. Data can be encrypted, and proper authentication measures can be taken to prevent data theft iii. Handling e-waste can be done following various accepted e-waste regulation **EP4:** i. How the accidents by the device may occur ii. How the data theft may take place and how the data can be misused iii. How can the project generate e-waste and what steps should be taken to control them **EP5:** Engineering ethics such as i. Fidelity ii. Responsibility iii. Accountability Can be achieved. **EP6:** Our project can be beneficial for the Crab Farmers, Researcher, Businessman, Government **EP7:** Replaceable components
CO5	Identify and apply modern engineering and IT tools for the design and development	**K6:** Proteus and Machine Learning simulation tool	**EP1:** We know simulation tools for devices and machine learning. **EP2:** i. Use of image recognition and sound recognition ML model

	of the capstone project.		ii. Placement of the product **EP4:** i. Data can be overfit ii. Noisy data from physical sensors iii. System can collapse iv. Underwater sensors may require frequent maintenance **EP5:** We fulfill various engineering ethics such as: i. Honesty ii. Integrity iii. Promise-keeping
CO6	Assess and address societal, health, safety, legal, and cultural aspects related to the implementation of the capstone project considering the relevant professional and engineering practices and solutions.	**K7:** **Societal:** Time and Cost-efficient and recyclable Health: Device containing non-toxic components **Safety:** Low Power Components **Legal:** No legal issues **Cultural:** Beneficial traditional crab farming	**EP2:** i. Low probability of device malfunction or overheating can cause fire or serious accident ii. Data theft can cause legal issues iii. Improper handling of e-waste can affect the environment **EP5:** Engineering ethics such as i. Fidelity ii. Responsibility iii. Accountability is achieved. **EP6:** Crab Farmer, Businessman, Government
CO7	Assess and address the sustainability and impact of the capstone project in societal and environmental contexts	**K7:** **Sustainability:** We will use green energy (solar), E-waste management, use nontoxic components. **Impact:** Introduction of new technology in crab culture and also a possible positive contribution to socio-economy.	**EP1:** We know the fundamentals of green computing and the importance of green energy, we understand the role of crab farming and fattening in the life of crab farmers in the coastal area **EP2:** Solar energy is not always available and 100% waste management is not possible, the project principle can be modified and used unethically **EP3:**

			Finding a solution for consistent clean energy, the impact of crab cannibalism, and water parameters on crab farmers **EP4:** Lack of well-designed national e-waste management framework **EP5:** Engineering ethics such as i. Fidelity ii. Responsibility iii. Accountability is achieved. **EP6:** Wide range of people such as users, people of local environment and society, seller/reseller, exporters, customers, etc. **EP7:** Current socio-economical status of the crab farmers or fatteners
CO8	Apply professional and engineering ethical principles and practices for the implementation of the capstone project	**K7:** Professional: We kept environmental and user safety, our project is within our area of competence. Ethical: We collected our resources from reputed and open sources. We will not collect and share any personal data of the user.	