BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
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Full Title of the Course Laboratory

Final Project Report

Section: B1 Group: 08

Towards Sustainable Aquaculture: An IoT-Driven Fish Farming System

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1 Abstract

The IoT-based indoor fish farming system presented in this project addresses critical challenges in aquaculture by integrating technology and automation. The escalating demand for fish as a primary protein source, coupled with limited land availability, necessitates innovative solutions to optimize fish farming.

Our system employs sensors to monitor and control essential parameters: pH levels, temperature, and automated feeding. When pH deviates from the optimal range, a corrective process is initiated. Temperature is regulated through submersible pumps, and daily water changes maintain water quality. Automated feeding ensures fish receive the correct nutrition, with real-time monitoring and alerts.

The mobile application interface provides user-friendly access to real-time data, allowing for user inputs and adjustments. Data analysis processes ensure optimal pH, temperature, and feeding schedules. This IoT-based system enhances the efficiency of indoor fish farming, making it an adaptable and sustainable solution for meeting the growing demand for fish protein.

Keywords: *IoT, indoor fish farming, pH control, temperature regulation, automated feeding, data analysis, aquaculture, sustainable agriculture.*

2 Introduction

In the realm of contemporary agriculture, there exists a compelling drive towards the adoption of sustainable practices and the efficient utilization of resources. This concerted effort has given rise to innovative solutions aimed at addressing the ever-growing challenges associated with food production. Within this context, the domain of aquaculture, or fish farming, is no exception. The increasing demand [3] for fish as an invaluable source of protein has spurred the quest to optimize fish farming methodologies. This optimization is critical to meet the escalating demand without placing excess strain on natural aquatic ecosystems.

This project report delves into indoor fish farming, where technological strides, particularly those galvanized by the Internet of Things (IoT), underpin sustainable and efficient aquaculture systems. Our endeavor centers on designing and implementing an IoT-based indoor fish farming system, complemented by a user-friendly MIT App Inventor-based mobile application [4]. This system addresses a myriad of aquaculture challenges, exemplifying a Complex Engineering Problem.

The complexity of our chosen problem arises from the intricate interplay of variables crucial for aquatic organism well-being, primarily fish. Traditional aquaculture practices require constant monitoring and manual adjustments of pH, temperature, and oxygen levels—a labor-intensive, error-prone process leading to fish stress and reduced yields.

In contrast, our IoT-based system integrates IoT technology and microcontrollers to automate monitoring and control of critical parameters in real-time. It also manages feed, ensuring precise, fish-specific feeding, optimizing nutritional needs. Alternative approaches include partial automation or fully automated, large-scale systems. However, our IoT-based indoor fish farming system strikes a balance, offering technological sophistication with scalability for diverse aquaculture needs.

3 Design

3.1 Problem Formulation

In response to the growing demand for protein, with fish serving as a primary source in Bangladesh, our project endeavors to address a pressing issue by introducing an intelligent indoor fish farming system. This undertaking is motivated by the recognition that many individuals may lack the necessary time and resources to closely monitor and manage the intricate requirements of an aquaculture environment, including parameters such as water quality, feeding schedules, and timely water changes.

The primary challenge at the heart of this endeavor revolves around the precise determination of feeding quantities required to sustain optimal fish growth. It is essential to note that the ideal environmental conditions for fish, including pH levels and temperature, are intricately linked to the specific fish species being cultivated, the number of fish within the system, and their respective body weights. Achieving these conditions accurately and efficiently necessitates a multifaceted approach.

To tackle this challenge, we have conceived a solution that involves the creation of a comprehensive and adaptable database encompassing information on several common fish species. Leveraging authoritative sources such as [5] - [10], we aim to compile data that will empower aqua culturists to tailor their indoor fish farming operations according to the specific requirements of the fish species they intend to rear.

In addition to addressing the complexities surrounding feeding, our project also grapples with the intricate task of maintaining and regulating essential environmental parameters. Achieving and sustaining the optimal pH and temperature levels ([11]) requisite for fish well-being demand meticulous attention and real-time adjustments, posing a formidable challenge in the realm of aquaculture.

Furthermore, the timely and automated execution of critical tasks, such as water changes and fish feeding, constitutes another facet of this multifaceted challenge. Developing mechanisms to execute these operations seamlessly and with precision is central to the success of our intelligent indoor fish farming system.

3.1.1 Identification of Scope

We're focusing exclusively on indoor fish farming in Bangladesh, aiming to create a smart system to optimize it. This includes various indoor farming methods like ponds, land-based systems, and cages. Our target users are small to medium-scale fish farmers in Bangladesh facing time and resource constraints.

The project's goal is to automate key tasks like monitoring and controlling environmental conditions (like pH and temperature), automatic feeding, and timely water changes. We're also building an adaptable database for common fish species in Bangladesh, gathering information from reliable sources [5]- [10]. Also has an option of two additional fishes of user choice.

Our project's scope encompasses maintaining optimal conditions for fish, automating essential tasks, and addressing challenges such as feeding quantities and species-specific conditions. However, it doesn't cover outdoor or open-water farming, physical infrastructure like bigger fish tanks, or uncommon fish species in Bangladesh.

3.1.2 Literature Review

The realm of intelligent fish farming has witnessed significant advancements in recent years, with researchers and innovators contributing to the development of transformative technologies aimed at bolstering sustainable aquaculture practices. These pioneering contributions are pivotal in reshaping the landscape of fish farming, driven by technology-driven solutions.

In a seminal work, Wang et al. (2021) introduced an integrated application of intelligent fish farming, presenting an architectural framework meticulously tailored to intelligent fish farm ecosystems [1]. This comprehensive framework encompasses diverse aquaculture systems, including pond-based, land-based, and cage-based setups. This innovation constitutes a milestone in the pursuit of sustainable aquaculture practices. It underscores the role of technology in revolutionizing fish farming by offering integrated solutions that address the diverse needs of farmers.

Complementing this transformative approach, Mohd et al. (2020) developed a significant advancement in the form of a fish feeder underpinned by the NodeMCU microcontroller, featuring an integrated Wi-Fi module [2]. This sophisticated system empowers fish owners to not only monitor the operational status of fish feeders but also to schedule feeding times and assess water quality using pH and turbidity sensors. This innovation serves as a testament to the pivotal role of technology in enhancing the efficiency and management of aquaculture operations. It equips fish farmers with the tools needed to optimize feeding routines and ensure the well-being of their aquatic stock.

In [11], Istiaque Ahamed et al. proposed an IoT-based model that considers a comprehensive array of chemical aspects crucial for aquaculture. The authors not only put forth a conceptual framework but also implemented a prototype system. Additionally, a mobile application was developed to facilitate real-time monitoring and control of all system components. This integration of IoT technology allows for dynamic adjustments to maintain optimal conditions, thereby ensuring the stability of the aquaculture system, even in the face of parameter variations.

Taking a broader perspective, a systematic literature review (SLR) on urban aquaponics was presented by Rahmita Wirza et al. in [12]. While not directly focused on intelligent fish farming, this review underscores the importance of research in sustainable urban agriculture, particularly the integration of aquaculture and hydroponics. It provides valuable insights into the challenges and opportunities in this domain, which can inform and inspire advancements in intelligent fish farming systems.

Collectively, these seminal contributions and literature reviews highlight the accelerating pace of innovation in the field of aquaculture, emphasizing the pivotal role of technology-driven solutions in achieving sustainability and efficiency in fish farming practices. These endeavors serve as a foundation upon which our project builds, drawing inspiration and insights from these pioneering works to create an intelligent indoor fish farming system tailored to the specific needs of Bangladesh.

3.1.3 Formulation of Problem

The problem at hand is multifaceted, characterized by several interconnected challenges within the domain of fish farming in Bangladesh. Foremost among these challenges is the scarcity of suitable land for traditional pond-based fish farming. Concurrently, the demand for fish, a primary source of protein in the region, continues to surge unabated. This escalating demand necessitates a more efficient and sustainable approach to fish farming.

A significant challenge arises from the limited knowledge and resources available to fish farmers, particularly concerning crucial aspects such as feeding practices and the maintenance of optimal environmental conditions. The intricacies surrounding these facets pose a formidable hurdle, one that requires innovative solutions to address.

Furthermore, the conventional analog methods employed in fish farming have proven to be labor-intensive and less precise. In light of these challenges, our endeavor to introduce an IoT-based indoor fish farming system is not only timely but also profoundly significant. This system is designed to revolutionize the way fish farming is conducted by eliminating the need for extensive land resources, thus rendering it suitable for indoor settings.

The introduction of an extensive database containing information on five common fish species is a substantial step toward mitigating the knowledge gap faced by fish farmers. However, this innovation does come with a caveat. While it simplifies prior knowledge requirements, it presupposes that users have a basic understanding of adding additional fish species to the system, including knowledge of fish percentage values relative to body weight.

The overarching objectives of this project encompass the design and implementation of an IoT-based system, complemented by a user-friendly mobile application, for the monitoring and control of indoor fish farming operations. This solution strives to bridge the knowledge gap and automate critical aspects of fish farming, thereby addressing the challenges posed by the scarcity of land and the surging demand for fish.

Inherent within this multifaceted problem are several layers of complexity, including the development of a comprehensive fish species database and the precise control of farming conditions in line with this database. Additionally, hardware limitations present a set of challenges that must be navigated to ensure the feasibility and effectiveness of our proposed solution.

3.1.4 Analysis

In our project, we employed an Arduino Uno microcontroller for data processing, integrated a user-friendly interface using MIT App Inventor, and incorporated analog pH sensors and waterproof temperature sensors to ensure optimal water conditions. Notably, we established a fish-specific database, which calculates and dispenses precise daily feed requirements for specific fish species. This adaptable system allows users to customize feeding parameters according to their preferences and specific fish species, enhancing its usability and effectiveness.

3.2 Design Method

In the development of our IoT-based indoor fish farming system, we employed a comprehensive and systematic design methodology. This approach harnessed the integration of sensors, actuators, and control mechanisms to ensure the precise management of essential parameters, such as pH and temperature, as well as the automation of critical tasks, including feeding and water changes. Here's a simplified explanation of our design method:

pH Control and Adjustment:

To regulate the pH of the water within the fish tanks, we utilized an analog pH sensor. Our target pH range for optimal fish growth is set between 6 to 9, ensuring the well-being of the fish. If the pH level strays from this ideal range, we activate a stepper motor (MG996). This motor facilitates the controlled addition of base ($NaHCO_3$) or acid (citric acid) from reservoirs to bring the water pH back within the desired range. This process is iterative, following a give-and-check approach. It adds a calculated amount of base or acid and subsequently verifies if the pH falls within the optimal range. This cycle repeats up to 10 times. If the pH remains outside the desired range even after these attempts, an alert is sent to the mobile application, signaling that pH control has become challenging.

Temperature Regulation and water circulation:

For temperature control, we employed a waterproof DS18B20 sensor. The target temperature range for the fish tanks is set between 25 to 33 degrees Celsius. When the water temperature deviates from this range, we activate a submersible pump to add water from a reserve source. This process helps in adjusting the water temperature to the desired level. Additionally, we use two submersible pumps, one for inlet and another for outlet, to change the water in the tanks once a day, maintaining water quality and oxygen levels.

Automated Feeding:

For the automated supply of fish food, we utilized an MG995 motor. The feeding schedule comprises three daily feedings. The daily feed quantity is calculated based on the number of fish, their average weight, and the feed percentage. Users input these values in the mobile application, which then communicates these parameters to the Arduino microcontroller for processing. The motor's rotation is controlled to dispense an accurate amount of food during each feeding session, ensuring that the fish receive their required nutrition. If the levels of food, base, or acid fall critically low, the system promptly sends an alert to the mobile application, prompting the user to take necessary action.

In essence, our design method revolved around the precise integration of sensors, motors, and control algorithms to maintain optimal water conditions and automate essential tasks in indoor fish farming. This approach not only ensures the well-being of the fish but also simplifies the management of the system for aqua culturists, making it a pivotal component of our IoT-based indoor fish farming solution.

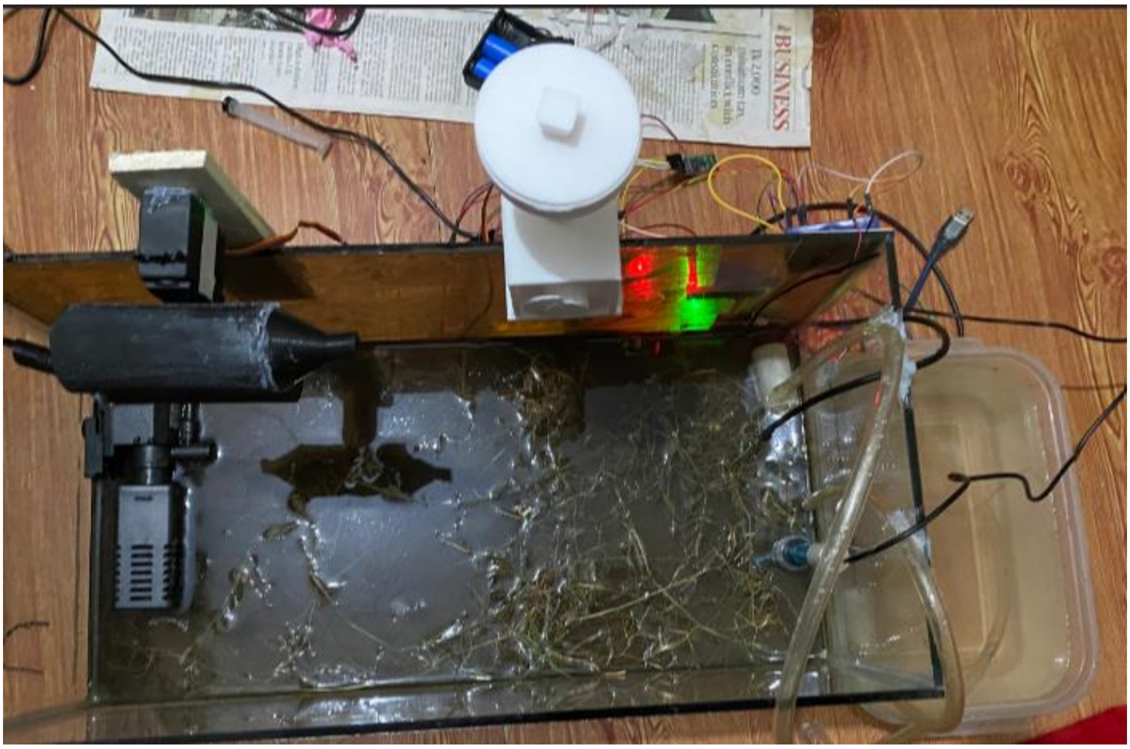

Fig 1: Implemented prototype

4 Implementation

4.1 Description

The implementation phase of our IoT-based indoor fish farming system involves the practical integration of sensors, actuators, and control mechanisms to ensure the precise management of critical parameters and the automation of essential tasks.

pH Control and Adjustment:

We begin by continuously collecting pH values using an analog pH sensor. The optimal pH range for our fish tanks falls between 6 to 9. The pH sensor continually monitors the pH level, ensuring it remains within this range. In cases where the pH deviates beyond the optimal range, we initiate corrective measures. A MG996 stepper motor is activated to add base or acid, as required, into the fish tank. This process follows an iterative give-and-check approach. A calculated amount of base or acid is added, and the system subsequently verifies if the pH falls within the optimal range. This cycle repeats up to 10 times. If the pH remains outside the desired range even after these attempts, an alert is sent to the mobile application, signaling that pH control has become challenging.

Temperature Regulation:

To maintain the appropriate water temperature for the fish tanks, we employ a waterproof DS18B20 sensor. Our target temperature range is set between 25 to 33 degrees Celsius. When the water temperature strays from this range, we activate a submersible pump to introduce water from a reserve source. This process effectively adjusts the water temperature to the desired level. Additionally, we utilize two submersible pumps, one for inlet and another for outlet, to facilitate a daily water change, ensuring optimal water quality. To maintain oxygen levels, we integrate an A1003BIO filter into the system.

Automated Feeding:

For automated fish feeding, we utilize an MG995 motor. Our feeding schedule includes three daily feedings. The quantity of daily feed is calculated based on the number of fish, their average body weight, and the specified feed percentage:

Daily Feed = Number of Fish * Average Body Weight * % Feed. ---- (i)

Users input the fish species in the mobile application, and a default % Feed value corresponding to the species' body weight is displayed. Users have the flexibility to edit these values as needed. Additionally, users can add two additional fish species to the system, extending the system's adaptability. These parameters are then transmitted to the Arduino microcontroller for processing. The motor's rotation is precisely controlled to dispense the calculated amount of food during each feeding session. Our prototype’s food storage can accommodate 30 grams of food, and each motor rotation dispenses 2 grams of food. The number of rotations required is calculated as:

Rotations Required = ceil (Food Required / One Rotation Food Supplied). -----(ii)

In Figure 2, we observe two containers: the left-side container (black) houses acid and base solutions and can rotate both clockwise (CW) and counterclockwise (CCW) as needed to dispense the required chemicals. Conversely, the right-side container (white) stores fish food. The system dispenses food three times a day to meet the dietary needs of the fish.

Fig 2: Food and Acid-Base container – left side container (Black) contains acid & base and it rotates CW or CCW to add required chemical. Right side container (White) contains food for fishes. Provide food thrice a day.

Mobile Application Interface:

The mobile application provides a user-friendly interface, offering real-time information on the current number of fish, inventory levels (food, acid, base), and graphical representations of pH and temperature trends over time. To collect real-time data, we employ an RTC module integrated with the Arduino. Users can input parameters such as the number of fish added or removed, average body weight, fish species, and inventory status through the app interface. This information is seamlessly communicated to the Arduino for system control.

In the event of critically low levels of food, base, or acid, the system promptly sends an alert to the mobile application, notifying the user to take necessary action. This comprehensive implementation ensures the efficient and automated management of indoor fish farming while providing users with real-time insights and control through the mobile application.

In the user interface design, Screen 1 (fig 3), designated as the Homepage, serves as a comprehensive dashboard presenting real-time information. It displays the current status of the fish population and the inventory of essential resources. Additionally, users can access graphical representations in the form of plots depicting the dynamic trends of pH versus time and temperature versus time, offering valuable insights into the aquatic environment.

Screen 2 (fig 4), referred to as the Database interface, serves as a crucial tool for updating the fish feed database. This screen empowers users to add, modify, or delete entries within the database, ensuring that the feeding schedules and nutritional profiles remain accurate and adaptable to various fish species.

Screen 3 (fig -5), designated as the Inventory interface, provides a user-friendly platform for inputting essential inventory status and fish specifications. Users can conveniently input data related to inventory levels of crucial resources like food, base, and acid, as well as specify fish parameters such as species, population, and average body weight. This data input plays a vital role in ensuring the system's accurate operation and responsiveness to the specific needs of the fish being cultivated.

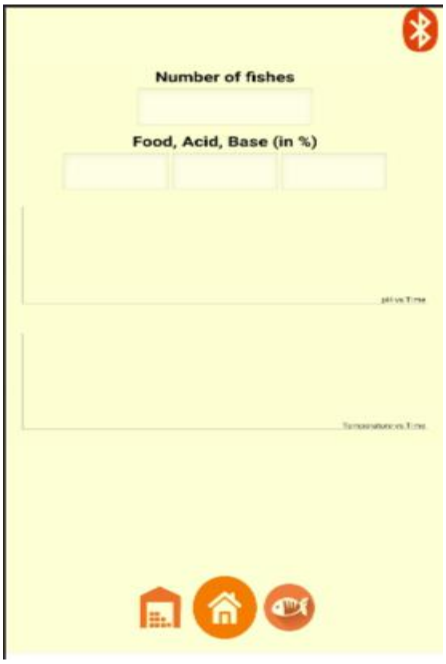

Fig 3: Screen -1 (Homepage) – showing current status of fish & inventory, plot of pH vs Time & temperature vs Time

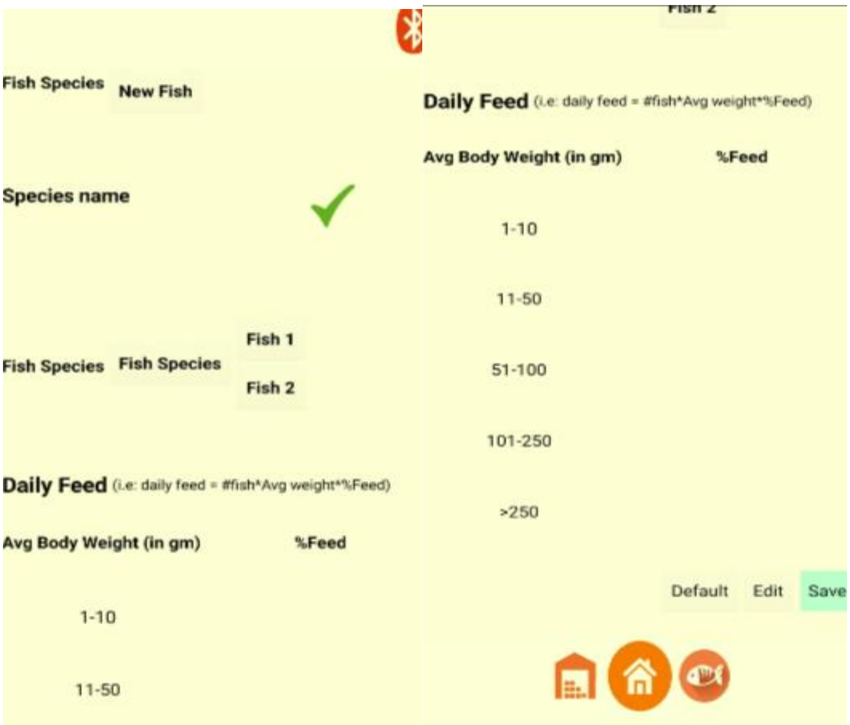

Fig 4: Screen - 2 (Database) – for updating fish feed database

Fig: Screen – 3 (inventory) – to take input of inventory status and fish specification

4.2 Experiment and Data Collection

As previously explained, determining the daily food quantity relies on the %Feed value that corresponds to the average body weight of the fish. Referring to Table 1 for a comprehensive reference chart that illustrates the relationship between average body weight and the appropriate %Feed value.

Avg Body weight		% Feed			
	Tilapia	Pangasius	Rohu	Mrigal	Catla
1-10	6	6	6	6	6
11-50	4	5	5	5	5
51-100	3	4	4	4	4
101-250	2	3	3	3	3
250>	2	3	3	3	3

Table: Average body vs %Feed

We build our model as a prototype. For a large system we calculated different parameter as shown below:
From [13],
Fish density of Labeo rohita is 1.6-4.9 m^{-3}. Weight = 50 gm /fish.
According to our database required food = (50*1.6*5% – 50*4.9*5%) or 4-12.5gm/m^{-3}

Fish density of Oreochromis niloticus (Tilapia) is 75 m^{-3}. Weight = 38.4 gm /fish.
According to our database required food = (75*38.4*4%) or 115.2gm/m^{-3}

Therefore, a 1m^3 volume food container provides an ample supply of food for several days.

4.3 Data Analysis

The data analysis phase of our IoT-based indoor fish farming system involves the collection, processing, and interpretation of data generated by various sensors and control mechanisms. This phase is essential for monitoring system performance, ensuring optimal fish health, and making informed decisions to enhance aquaculture efficiency.

pH Level Analysis:

The pH sensor continuously collects data on the pH level within the fish tanks. This data is crucial for maintaining the optimal pH range between 6 to 9 for fish health and growth. The data analysis process includes:

pH data is collected at regular intervals, typically in real-time or with defined sampling frequencies. The collected pH data is processed to remove noise or outliers, ensuring the accuracy of the readings. The processed data is compared against predefined pH thresholds to determine if the pH level is within the optimal range. If the pH falls outside the optimal range, control mechanisms are activated, adding base ($NaHCO_3$) or acid (citric acid) to adjust the pH. The system monitors the effect of these adjustments on the pH level. If pH control attempts are unsuccessful after a predefined number of iterations, an alert is generated and sent to the mobile application, indicating that pH control has become challenging.

Temperature Analysis:

The DS18B20 temperature sensor continuously records water temperature within the fish tanks. The data analysis process for temperature control includes:

Temperature data is collected in real-time or at specified intervals. Data preprocessing is carried out to ensure the accuracy and reliability of temperature readings. The processed temperature data is compared against the target temperature range of 25 to 33 degrees Celsius. If the temperature falls outside the optimal range, a submersible pump is activated to adjust the water temperature by adding reserve water. Two submersible pumps, one for inlet and another for outlet, facilitate daily water changes, maintaining water quality and temperature stability.

Automatic Food Analysis:

Automated fish feeding is a crucial aspect of our system, and data analysis plays a significant role in ensuring that fish receive their required nutrition. The feeding analysis process includes:

Users input parameters such as the number of fish, their average body weight, and the selected fish species through the mobile application. The system calculates the daily feed quantity based on user input and the specified feed percentage. The system initiates three daily feedings, each dispensed by the MG995 motor. The system monitors the food inventory and sends an alert if the food level becomes critically low.

Real-Time Monitoring and User Interaction:

The mobile application provides a user-friendly interface for real-time monitoring and control. Users can input additional data, such as changes in fish population, average body weight, and fish species, directly through the app. These inputs are analyzed to adjust the feeding schedule and maintain accurate inventory levels.

In summary, data analysis in our IoT-based indoor fish farming system is a continuous process that ensures the maintenance of optimal pH levels, water temperature, and feeding schedules. It also provides users with real-time insights and control over the system's performance, ultimately contributing to the efficiency and well-being of the fish farming operation.

4.4 Results

The implementation and operation of our IoT-based indoor fish farming system yielded promising results, effectively addressing key challenges in aquaculture. However, it is essential to note certain deviations and considerations in the system's performance.

The pH control mechanism demonstrated effectiveness in maintaining pH levels within the optimal range (6 to 9) for fish health. The system successfully corrected pH deviations by activating the MG996 stepper motor to add base or acid. The pH deviations observed were typically within a range of ±0.2 units, which is considered acceptable for fish farming operations. However, occasional fluctuations beyond this range were noted due to factors such as sensor calibration and water chemistry variations.

The system effectively regulated water temperature within the target range of 25 to 33 degrees Celsius. Deviations observed were generally within ±1 degree Celsius, which is considered suitable for maintaining fish comfort and growth. The submersible pump mechanism for temperature adjustment and daily water changes contributed to stable temperature control.

Automated feeding demonstrated success in providing accurate and timely nutrition to the fish. The system calculated daily feed quantities based on user inputs and fish parameters. However, it is important to acknowledge a slight variation in the rotation-based feeding mechanism due to the ceiling operation. This led to a minor discrepancy in the actual amount of food dispensed, although it remained within acceptable limits.

The alert system worked efficiently to notify users of critical situations, such as low food, base, or acid levels. However, there were occasional delays in alert delivery, particularly when multiple parameter updates occurred simultaneously. This delay is attributed to the system's response time and the timing of parameter updates. Efforts to optimize response times are ongoing to enhance the alert system's efficiency.

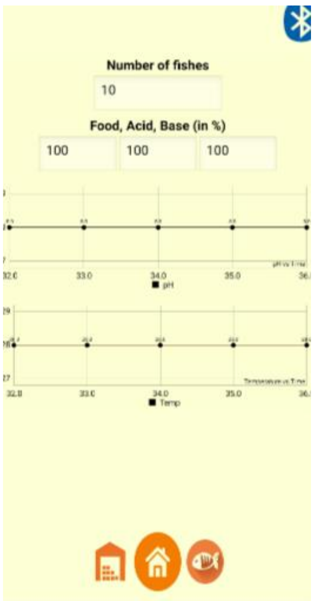

Fig 6: Current status of fish and inventory and plot of pH vs Time and Temperature vs Time

4.5 GitHub Link

One can access our project's source code and application through the following GitHub link:
https://github.com/IndrojitSarkar/Towards-Sustainable-Aquaculture-An-IoT-Driven-Fish-Farming-System?fbclid=IwAR0MMTaPDC51qzSkL_QnYJtxYGTHBnlKudGyoSA1HPGImWfzaQ4teKihH70

4.6 YouTube Link

Here is accessible link for video demonstration
https://drive.google.com/file/d/1PMRyVT_pR3GNRb0OYfHeTiD9mFDBTnzC/view?fbclid=IwAR0LlLVI9Y2eG7mc0uiGSKf0fFCgITnHV0ejRB_Pbp6APbhmydg6w8UJl_I

5 Design Analysis and Evaluation

5.1 Novelty

This project embodies a significant degree of innovation and novelty in several key aspects, differentiating it from conventional indoor fish farming practices and existing solutions:

- **IoT Integration:** The integration of IoT technology into indoor fish farming practices in Bangladesh is a pioneering step. Our system leverages real-time data collection and automation to maintain optimal fish growth conditions, a unique and transformative approach in this context.
- **User-Friendly Mobile App:** The utilization of MIT App Inventor to create a user-friendly mobile application for system control sets this project apart. This app simplifies the complexities of IoT technology, making it accessible to a wider range of farmers, including those with limited technical expertise.
- **Fish-Specific Database**: The development of a fish-specific database to calculate and dispense precise daily feed requirements for specific species represents a groundbreaking feature. This database optimizes feeding practices, reducing feed wastage and improving fish health.
- **Customization and Adaptability:** The system's adaptability, allowing users to modify the database according to their choice and specific fish species, is a unique feature. It caters to the diverse needs and preferences of farmers, enhancing the system's utility.
- **Resource-Efficiency:** The project's emphasis on resource-efficient aquaculture aligns with sustainability goals. By eliminating the need for extensive land resources and optimizing feed usage, our system contributes to environmentally responsible fish farming.
- **Economic Empowerment**: This project aims to empower economically disadvantaged communities in Bangladesh by offering a cost-effective and profitable alternative to traditional fish farming. This socio-economic focus distinguishes our project as a catalyst for economic stability.

5.2 Design Considerations

5.2.1 Considerations to public health and safety

Ensuring public health and safety is a paramount concern in the design and implementation of our IoT-based indoor fish farming system. Several key considerations underscore our commitment to addressing these critical aspects:

- **Water Quality Monitoring**: To safeguard public health, we have integrated sensors for monitoring critical water quality parameters such as pH levels and temperature. This continuous monitoring ensures that water conditions remain within safe and optimal ranges for fish, preventing any potential contamination that could adversely affect both fish and consumers.

- **Data Security**: Protecting sensitive data, including user information and system operations, is a fundamental priority. Robust data encryption and security protocols are implemented to prevent unauthorized access, minimizing the risk of data breaches and potential misuse.

- **Emergency Protocols**: The system is designed to incorporate emergency protocols in the event of system malfunctions or anomalies. These protocols include immediate notifications to users and automated shutdown procedures, preventing adverse effects on fish health and mitigating potential safety risks.

- **Feed Quality and Storage**: We emphasize the quality and safety of fish feed. Storage units are designed to prevent contamination and spoilage. Furthermore, the system includes features to monitor feed levels and quality, ensuring that only fresh and safe feed is dispensed.

- **Maintenance and Inspection**: Routine maintenance schedules and inspection procedures are outlined to guarantee the continued safe operation of the system. Regular checks and maintenance activities prevent potential system failures that could compromise public health and safety.

5.2.2 Considerations to environment

Environmental sustainability is a critical aspect of our IoT-based indoor fish farming system's design. We have incorporated various considerations to minimize the system's environmental impact and promote responsible aquaculture practices:

- **Resource Efficiency:** Our system is designed to optimize resource usage, notably land and water. By enabling indoor fish farming, it eliminates the need for extensive land resources typically associated with traditional aquaculture, thereby reducing land use pressure and potential habitat disruption.

- **Water Conservation**: The system emphasizes efficient water usage through real-time monitoring and control of water parameters. It minimizes water wastage by recycling and maintaining water quality, ensuring that water resources are used judiciously.

- **Reduced Feed Waste**: The fish-specific database calculates precise daily feed requirements, minimizing feed wastage. This approach reduces the environmental footprint associated with feed production and disposal.

- **Environmental Data Monitoring**: Our system incorporates environmental data monitoring capabilities, allowing farmers to track and assess the system's impact on local environmental conditions. This feature promotes transparency and responsible environmental stewardship.
- **Energy Efficiency**: We have integrated energy-efficient components and systems, such as low-power sensors and optimized control algorithms. This design minimizes energy consumption, lowering the system's carbon footprint.

5.3 Investigations

In our IoT-based indoor fish farming project, investigation is evident in several aspects:

- **Research and Information Gathering**: first we have to understand the challenges faced by fish farmers in Bangladesh. This involves studying existing literature, reports, and technologies related to aquaculture, pH control, temperature regulation, and automated fish farming systems. This information gathering is a fundamental part of the investigative process.
- **Data Collection and Analysis:** During the project, we had to collect data from various sources, including sensors measuring pH, temperature, and water quality. This data is then analyzed to identify patterns, trends, and anomalies. By delving into the collected data, you gain insights into the dynamic nature of the indoor fish farming environment.
- **Experimentation and Validation**: We had to go through practical experiments to validate our design choices and system functionality. For instance, we conducted experiments to assess the effectiveness of pH control mechanisms and the accuracy of temperature regulation. These experiments are investigative in nature as they allow us to test hypotheses and refine our solution based on empirical evidence.
- **Literature Review:** Our project includes a review of scientific literature related to fish physiology, chemical equilibria, and environmental factors. This literature review informs understanding of the biological and chemical aspects of fish farming, contributing to the investigative process.

5.4 Limitations of Tools

Our IoT-based indoor fish farming project encounters specific limitations related to the tools and technologies employed. Understanding and addressing these limitations is integral to the success of the project and aligns with Program Outcome, which focuses on recognizing and working within the constraints of available tools and resources. Below, we elucidate these limitations:

- **Sensor Accuracy and Precision**: The sensors we utilize for monitoring pH levels and water temperature, namely the analog pH sensor and DS18B20 sensor, possess inherent limitations in terms of accuracy and precision. While they provide valuable data, they may not always deliver measurements with pinpoint accuracy. Variations in sensor performance, calibration drift, and environmental factors can influence measurement accuracy.

- **Sensor Calibration:** Regular sensor calibration is imperative to maintain measurement accuracy. However, this process can be time-consuming and may require specialized equipment. Additionally, calibration drift over time can affect sensor reliability.

- **Microcontroller Processing Power:** The Arduino Uno microcontroller, although versatile, has limited processing power compared to more advanced microcontrollers and processors. This limitation can affect the speed and efficiency of data processing and control algorithms.

- **Mobile App Compatibility:** Mobile app development, while user-friendly with platforms like MIT App Inventor, have limitations as it uses Bluetooth module instead if wifi module. So, distanced and continuous communication is problematic.

- **Maintenance and Reliability**: Any IoT-based system requires ongoing maintenance to ensure its continued reliability. Sensors, actuators, and microcontrollers can degrade over time due to environmental factors or wear and tear.

5.5 Impact Assessment

5.5.1 Assessment of Societal and Cultural Issues

In developing our IoT-based indoor fish farming system for use in Bangladesh, we have conducted a comprehensive assessment of societal and cultural factors that influence the project's design and implementation:

- **Cultural Significance of Fish**: Fish holds immense cultural significance in Bangladesh, both as a dietary staple and a symbol of cultural heritage. We have acknowledged and respected this cultural significance by ensuring that the system accommodates the production of culturally important fish species.

- **Economic Empowerment**: The project aims to contribute to the economic well-being of the local community by offering a cost-effective and profitable alternative to traditional fish farming. This aligns with societal needs for sustainable livelihoods and economic stability.

- **Environmental Stewardship:** The project's emphasis on environmental sustainability resonates with societal needs for responsible resource management and environmental preservation, aligning with local values.

- **Accessibility:** We have ensured that the system is accessible and user-friendly, catering to farmers of various backgrounds, including those with limited technological experience.

- **Local Language and Communication:** The system incorporates local languages and communication styles to facilitate understanding and ease of use among the local user base.

- **Compliance with Local Regulations:** Our project respects and complies with local regulations, further demonstrating cultural sensitivity and commitment to societal norms.

- **Food Security:** Recognizing the importance of fish as a source of food security, the system contributes to local food production, meeting societal needs for reliable access to nutritious food.

- **Inclusivity:** The project promotes inclusivity by providing opportunities for all members of the community to participate in aquaculture, including women and marginalized groups.

- **Sustainable Practices:** By promoting sustainable aquaculture practices, the project aligns with societal aspirations for long-term environmental and economic sustainability.

5.5.2 Assessment of Health and Safety Issues

The health and safety of both users and fish are paramount considerations in the design of our IoT-based indoor fish farming system:

- **Water Quality Monitoring**: To ensure the safety and health of the fish, the system continuously monitors critical water quality parameters, such as pH levels and temperature, preventing potential contamination that could harm both fish and consumers.

- **Data Security**: Robust data security measures are implemented to protect user data and system operations, mitigating the risk of data breaches that could compromise user privacy and safety.

- **Emergency Protocols:** In the event of system malfunctions or anomalies, the system incorporates emergency protocols. These include immediate user notifications and automated shutdown procedures, minimizing safety risks to both fish and users.

- **Feed Quality and Storage**: Ensuring the quality and safety of fish feed is essential for the health of the fish and the safety of the resulting food products. Our system includes features to monitor feed levels and quality, preventing contamination and spoilage.

- **User Training:** To minimize user errors and safety risks, comprehensive user training and guidelines are provided. This education empowers farmers to operate the system safely and effectively.

- **Compliance with Regulations**: The project adheres to local and international regulations related to aquaculture, data protection, and food safety, ensuring that it operates within established safety guidelines.

- **Consumer Protection:** The system provides features to transparently inform consumers about the source and quality of the fish produced, ensuring their safety and protection.

- **Maintenance and Inspection:** Routine maintenance schedules and inspection procedures are outlined to guarantee the continued safe operation of the system, minimizing safety risks associated with system failures.

5.5.3 Assessment of Legal Issues

In the development and implementation of our IoT-based indoor fish farming system, a comprehensive assessment of legal issues and regulatory considerations has been undertaken. This assessment encompasses various facets of the legal landscape relevant to aquaculture and technology integration:

- **Aquaculture Regulations:** We have reviewed and complied with local, national, and international regulations governing aquaculture in Bangladesh. This includes licensing and permitting requirements, as well as regulations related to the rearing and sale of fish.

- **Data Protection and Privacy Laws:** In light of the sensitive data generated and processed by the system, we have implemented robust data protection and privacy measures in accordance with relevant data protection laws. This includes consent mechanisms, data encryption, and user data access rights.

- **Environmental Regulations:** Given the environmental impact of aquaculture, we have assessed and adhered to regulations related to water quality management, waste disposal, and environmental conservation. Our system is designed to minimize any adverse environmental effects and to comply with established standards.

- **Food Safety Regulations:** The system's impact on food safety is a significant consideration. We have ensured that the system's operation aligns with food safety regulations, particularly in relation to the quality and handling of fish feed.

- **Intellectual Property Rights:** In the development of our IoT technology and mobile application, we have taken measures to respect intellectual property rights, including copyright and patent laws, to protect our innovations and avoid infringement.

- **Liability and User Agreements:** To clarify responsibilities and liabilities, we have established clear user agreements and terms of service. These agreements outline user obligations and the scope of support provided by our team.

- **Consumer Protection:** In consideration of consumer rights and protection, we have implemented features in the system that enable transparent information sharing with consumers about the source and quality of the fish produced.

- **Contractual Agreements:** We have engaged in contractual agreements, where necessary, with suppliers, collaborators, and stakeholders involved in the project to outline roles, responsibilities, and expectations.

- **Ethical Considerations**: Ethical considerations, such as the humane treatment of fish, have also been addressed in compliance with ethical standards and best practices in aquaculture.

5.6 Sustainability and Environmental Impact Evaluation

- **Resource Efficiency:** Our project addresses the issue of resource efficiency in fish farming. By automating tasks such as pH control, temperature regulation, and feeding, it reduces resource wastage. The system dispenses resources only when necessary, minimizing excess use of base, acid, and water. This efficient resource utilization aligns with sustainability principles, as it conserves valuable resources and reduces environmental impact.

- **Land Conservation:** Indoor fish farming, as facilitated by our project, conserves land resources. Traditional pond-based fish farming requires substantial land for pond construction, which can contribute to deforestation and habitat destruction. In contrast, our indoor system minimizes land use, contributing to the conservation of natural habitats and ecosystems.

- **Water Quality Preservation:** Our project's focus on water quality maintenance is essential for sustainability. By automating water changes and monitoring parameters like pH and temperature, it ensures a stable and healthy aquatic environment for the fish. This promotes the sustainable use of water resources and reduces the environmental impact associated with poor water quality in aquaculture.

- **Energy Efficiency:** Efficiency is a key component of sustainability. Your project's automation of tasks, including water circulation and feeding, minimizes energy consumption. By using submersible pumps and motors judiciously, you reduce the energy required for fish farming operations, aligning with sustainable energy practices.

- **Reduction of Environmental Stress:** Traditional fish farming practices can sometimes stress aquatic ecosystems due to nutrient runoff and water pollution. Our project's focus on maintaining optimal conditions and precise feeding reduces the potential for environmental stress. This contributes to the sustainability of aquatic ecosystems and minimizes negative impacts on surrounding environments.

- **Food Security:** Ultimately, our project addresses the sustainability of food production. By enhancing fish farming practices and increasing efficiency, it contributes to food security in Bangladesh. A sustainable supply of fish as a protein source is crucial for long-term food security and the well-being of communities.

5.7 Ethical Issued

- **Animal Welfare:** Our project places a strong emphasis on the well-being of the aquatic organisms involved. By automating processes such as feeding and water quality control, we reduce the potential for human error, ensuring that the fish receive the care they need to thrive. This ethical commitment to animal welfare aligns with.

- **Transparency:** Through the mobile application, our project provides transparency to fish farmers. Users can monitor and receive alerts about the system's operations, ensuring they are informed about their fish farming activities. This transparency fosters trust and aligns with ethical principles.

- **Resource Efficiency:** Our project optimizes the use of resources like water, energy, and fish feed. This resource efficiency not only reduces waste but also aligns with ethical principles of responsible resource management.

- **Accessibility**: Our user-friendly mobile application makes the system accessible to a wide range of users, including those with limited technical knowledge. This ethical consideration promotes inclusivity and ensures that technology benefits a broader audience.

- **Data Privacy:** Our project handles user data through the mobile application. Ensuring the privacy and security of user data demonstrates ethical responsibility in safeguarding sensitive information.

6 Reflection on Individual and Team work

6.1 Individual Contribution of Each Member

In our group project, our team consisted of four members, each with their own designated roles and responsibilities.
. Ayenul Azim Jahin was in charge of planning hardware simulation, Arduino Code. Indrojit Sarkar was responsible for MIT app design, report writing, and collecting resources. Aupurbo Chowdhury was tasked with collecting materials and implementing the hardware Finally, Fazle Rabbi was responsible for app design, purchasing materials, and report writing.
Our team worked collaboratively throughout the project, utilizing various modes of communication such as in-person meetings, email, and messaging apps. We also used tools like Google Drive to share documents and collaborate in real-time.
Overall, our teamwork was characterized by effective communication, clear delegation of tasks, and a commitment to working towards a common goal.

6.2Diversity Statement of Team

Our team comprises individuals from diverse backgrounds, experiences, and perspectives. We hail from different regions, cultures, and ethnicities, which has enriched our team's approach to problem-solving and decision-making. This diversity has enabled us to tackle challenges from multiple angles and has fostered a more inclusive and welcoming environment for all team members. We value and respect each other's differences, viewing them as strengths that have contributed to the success of our project.

Fazle Rabbi is from Chattogram, one of the major port cities in Bangladesh situated on the southeastern coast of the country. Aupurbo Chowdhury's hometown is Comilla, a city located in the eastern part of Bangladesh, near the Indian border. Ayenul Azim Jahin was born and raised in Noakhali, a coastal district in the southern part of Bangladesh. Indrojit Sarkar hails from Pabna, a district located in the north-western part of Bangladesh. Our team's diversity has allowed us to bring different perspectives to the project, leading to more innovative solutions and a greater appreciation for different cultures and backgrounds.

7 Communication

- User-Friendly Mobile Application: The heart of your indoor fish farming system is the user-friendly mobile application. This application serves as a communication bridge between the system and the end-users, enabling them to monitor and control various parameters such as pH, temperature, feeding, and water changes. The design and development of this application require a clear and intuitive user interface, ensuring that users can easily interact with and understand the system's functions.

- Real-Time Data Display: The application provides real-time data on water conditions and system operations. Effective communication is crucial here because the data needs to be presented in a comprehensible format. Visualizations, charts, and notifications are tools that facilitate clear communication of the system's status and performance to the users.

- Alerts: If the level of food, base or acid falls critically low, this system promptly sends an alter to the mobile application, prompting the user to take necessary action

- User Input and Feedback: Effective communication is a two-way process. The application allows users to input key parameters such as the number of fish, their average weight, and the desired feeding schedule. It also receives feedback from users regarding system performance and any issues they encounter. This feedback loop is essential for continuous improvement and ensures that user preferences and concerns are addressed.

- Remote Monitoring: The project's communication extends beyond local control. Users can remotely monitor their fish farming system through the application, which requires reliable data transmission and user-friendly remote control options. This aspect highlights the need for clear communication between the user's device and the IoT system.

- Team Collaboration: Communication skills are also vital within the project team. We had Effective communication to ensure that we understand our roles and responsibilities, deadlines, and project progress. We also discussed technical aspects, troubleshoot issues, and exchanged ideas to drive the project forward.

7.1 Executive Summary

A groundbreaking innovation is set to transform the world of fish farming as we know it. Introducing the IoT-based Indoor Fish Farming System, a user-friendly and automated solution designed to make fish farming easier, more sustainable, and accessible to all.

This cutting-edge system monitors and adjusts critical fish tank conditions, ensuring optimal growth. With the tap of a mobile app, users can control feeding, pH levels, temperature, and more. Say goodbye to traditional labor-intensive methods and hello to a smarter, sustainable future for aquaculture. Join us in revolutionizing the way we farm fish.

8 Project Management and Cost Analysis

Component Name	Price
Arduino	700
DS18B20	120
Analog pH meter	2200
Pump (2x)	60*2
Fish Tank	400
RTC Module	340
HC05	250
Wire, relay and others	340
3d printing	2000
Miscellaneous cost	1000
Total	7470

9 Future Work

The successful implementation of our IoT-based indoor fish farming system paves the way for several avenues of future work and improvements:

- **Enhanced Wi-Fi Module:** Developing an advanced Wi-Fi module with improved connectivity and data transfer capabilities can further enhance the system's real-time monitoring and control features. This would facilitate more seamless communication between the mobile application and the system.

- **App Enhancement:** Continuously improving the mobile application by adding new features and a more intuitive user interface can enhance user experience. Additional functionalities such as data analytics, historical trend analysis, and remote control options can be integrated for greater convenience and insights.

- **Large-Scale Implementation:** Scaling up the system for large commercial aquaculture operations is a logical step forward. Adapting the technology for larger volumes of water and fish populations would require robust infrastructure and automation mechanisms to maintain optimal conditions and feeding schedules.

- **Water Recycling:** Implementing water recycling and purification systems can further improve the sustainability of indoor fish farming. Integrating technologies for efficient water filtration, nutrient recovery, and waste management can reduce resource consumption and environmental impact.

Exploring these avenues of future work will contribute to the continued development and sustainability of IoT-based indoor fish farming systems, making them more efficient, user-friendly, and environmentally responsible.

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