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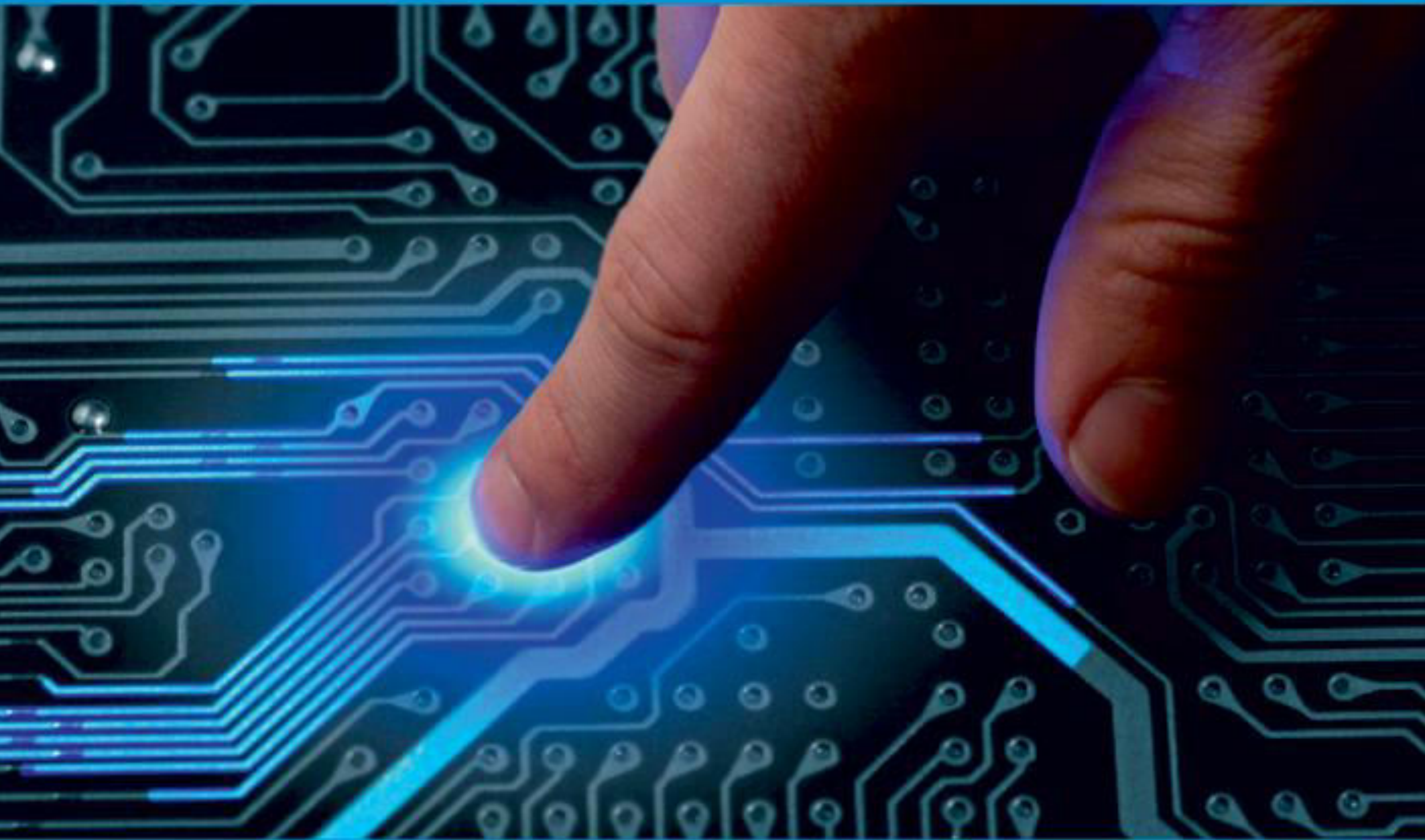

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IoT-Driven Fish Monitoring System for Enhanced Aquaculture Management

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ABSTRACT: Aquaculture primarily involves cultivating aquatic organisms by providing suitable environments for various purposes, including commercial, recreational, and public uses. This paper aims to enhance fish production and maintain the aquatic environment of aquaculture in Bangladesh. It presents the use of Internet of Things (IoT) based devices to monitor the essential needs of aquaculture and support fisheries. By using these devices, various water parameters will be monitored to create a better living environment for fish. The devices include sensors that detect the Potential of Hydrogen (pH) level and water temperature. Additionally, there are sections for measuring dissolved oxygen and ammonia levels using testing kits, which are crucial for proper fish farming. An Android-based mobile application has also been developed. In this system, farmers, fishermen, and individuals involved in aquaculture will use the Android application. Through this application and with the help of the device, users will be notified about the levels of dissolved oxygen, ammonia, pH, and water temperature. This monitoring system will help fish farmers take necessary steps to prevent any disturbances in the aquatic environment. Given that Bangladesh is a riverine country and fish farming significantly impacts its economy, maintaining good health to produce more fish is essential. However, the country's fisheries may lack the expertise to understand the essential elements required for fish growth and management. This system could assist them in measuring parameters and providing the necessary resources to increase fish production.

I. INTRODUCTION

The significance of aquaculture cannot be overstated. In aquaculture systems, fish are cultivated in confined artificial water bodies, such as tanks, where they live, eat, grow, and excrete waste. Without a natural water source, water quality deteriorates rapidly, impacting the growth and health of the fish. Thus, maintaining water quality is crucial in aquaculture to ensure optimal fish growth and health. The proposed system aims to meet the demand for fish by preserving the water quality necessary for increased fish production, thereby boosting economic value. This system will make fisheries more efficient and improve human health by providing an abundant supply of fish.

Aquaculture contributes approximately 3.69% to the country's total Gross Domestic Product (GDP) and accounts for 22.60% of the agricultural GDP. Over the past decade (from the fiscal year 2004–2005 to 2013–2014), the sector has seen a steady growth rate of about 5.38% annually. From 2009–2010 to 2013–2014, growth rates ranged from 7.32% to 4.04%. By the 2015–2016 periods, Bangladesh had become the world's fifth-largest aquaculture producer, with wild capture fisheries contributing 16.78% (oceanic) and 83.22% (freshwater) to the total. Aquaculture constitutes over half of the country's total fish production (55.15%). Pond culture is pivotal in Bangladesh's aquatic production, representing 85.8% of the total output and covering 57.7% of the aquatic land area.

Bangladesh's inland fish cultivation includes two primary systems: open and closed inland water systems. The inland water bodies include numerous ponds, seasonal water bodies, pen culture areas, cage culture sites, and farms. Ponds alone cover 384,700 hectares, with seasonal water bodies accounting for 136,273 hectares. As of 2016–2017, there are 833,752 hectares dedicated to fish farming to support the economy. According to the Department of Fisheries (DOF), carp production is dominant in pond culture, with domestic Indian major carps and silver carp making up about 59% of pond fish production. Non-native species account for 19%, and Indian minor carps and other non-native carps contribute to 88% of the pond fish production in Bangladesh.

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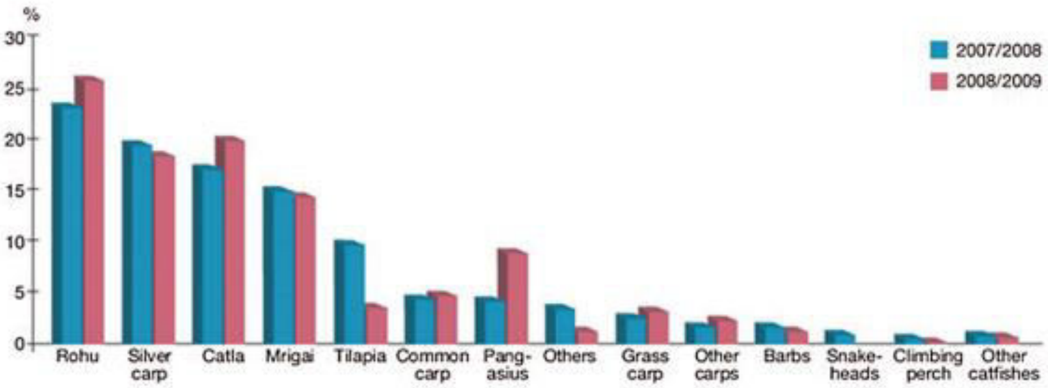

Figure 1: Contribution of each species to total pond production in 2007/2008. (Source: modified from DOF 2009a, 2010) [8]

The aquaculture sector generates significant revenue through the export of large quantities of fish and prawns. For instance, in July 2020, the export of fish and prawns brought in approximately 2,720,000 BDT (Bangladesh Taka). Additionally, around 1.4 million women are employed in various aspects of the fish industry, including fishing, farming, handling, and processing, which provides them with their livelihoods. Fisheries and aquaculture are crucial for earning foreign exchange and are the second-largest export industry in Bangladesh. The country exports a wide range of fish products to about 60 countries globally, with major importers including the European Union (EU), the USA, and Japan.

Bangladesh has achieved substantial earnings from fish exports, with the sector generating approximately BDT 4,776.92 crore in 2013–2014 from the export of 77.33 thousand Metric Tons (MT) of fish and seafood products, marking the highest earnings in the past decade. Export earnings remained high in 2016–2017, reaching about BDT 4,287.64 crore from the export of 68.31 thousand MT of fish and related products.

Various fish species are cultivated in Bangladesh, with tilapia being the most profitable and widely farmed across the country. Shrimp and crab are also extensively cultivated due to their high demand in both local and international markets, driving their high prices. Significant quantities of shrimp and crab are exported, along with other common species such as bhetki, tangra, horina, and chingri found in saltwater bodies. Common freshwater fish cultivated include Katla, rui, mrigal, common carp, boal, pabda, chital, koi, shol, gozar, and various types of catfish.

As the economy grows rapidly, environmental challenges, particularly water pollution, are becoming increasingly prevalent. Key water quality indicators include Dissolved Oxygen (DO), Total Ammonia-Nitrogen, Nitrite, pH, Alkalinity, Hardness, Carbon Dioxide, Salinity, Iron, Chlorine, Hydrogen Sulfide, and Clarity. Traditionally, water samples are collected manually and tested in laboratories, a time-consuming process. There is a need for innovative solutions to address these challenges more efficiently.

Belen [14] developed an aquaculture monitoring system that tracked three parameters: pH level, temperature, and flow rate. In this system, no correlation was found between flow rate and either pH or temperature, but temperature was inversely proportional to pH. Tolentino et al. [15] created a system that monitored parameters such as temperature, pH, Oxidation-reduction Potential (ORP), salinity, and dissolved oxygen using an aquarium heater, Sodium Hydrogen carbonate, and water pump, which were displayed on a web application. However, this system was not suitable for large-scale aquatic production.

Raj et al. [16] developed a monitoring system using pH, temperature, and ultrasonic sensors to oversee the feeding of aquatic organisms in an aquarium. Harun et al. [17] built a system with pH, temperature, and Dissolved Oxygen (DO) sensors to assess water quality. Rosalin et al. [18] designed a system featuring five sensors: distance, ammonia, salinity, oxygen, and temperature, though it was noted that this system could be costly.

Saha et al. [19] introduced an IoT-based automated monitoring system for fish farms that used sensors for temperature, pH, conductivity, and water color. However, this setup might be insufficient for large-scale operations. Authors in [20] proposed an IoT-based smart agrotech system focusing on humidity, temperature, and soil moisture, but it was not

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tailored for aquaculture. Authors in [21] discussed a VANET for health monitoring applications unrelated to aquaculture.

In this research, an IoT-based fish monitoring system for aquaculture has been developed to address the shortcomings of existing systems. This new system allows fishermen and aquaculture professionals to measure water quality parameters and monitor fish health. An Android mobile application has been developed to provide real-time measurements of these parameters. By reducing costs and measuring crucial water quality factors, the system aims to enhance production levels in aquaculture.

In aquaculture, several critical issues must be addressed to ensure the health of fish. One major concern is oxygen depletion, which refers to a low level of Dissolved Oxygen (DO). Insufficient DO can lead to fish mortality, with levels between 2–4 mg/L causing distress to nearly all fish species. Another important factor is the pH level of the water, which must be maintained within a suitable range. Water temperature is also crucial, as different fish species thrive in different temperature ranges. Monitoring temperature is essential for maintaining optimal conditions for fish survival.
Ammonia, often referred to as the "silent killer" in aquaculture, poses a significant threat. If ammonia levels are not controlled, fish can die overnight. The ideal DO level for fish is between 6.5–8 mg/L and 80–120% saturation. Falling below this range can cause suffocation and death. The pH level should be maintained between 6.5 and 9.0; deviations from this range can be harmful to fish.

Temperature requirements vary by species: coldwater fish generally cannot tolerate temperatures above 20–25°C, while warm-water species can survive at temperatures between 10–15°C but will not reproduce below 20°C. Tropical species require higher temperatures, thriving between 25–30°C and dying at temperatures below 10–20°C. Ammonia levels should be kept within specific ranges: 0.3 to 0.9 mg/L for coldwater fish, 0.7 to 3.0 mg/L for warm-water fish, 0.6 to 1.7 mg/L for marine fish, and 0.7 to 3.0 mg/L for marine shrimp. Elevated ammonia levels can be fatal to fish, making careful monitoring of these parameters crucial for successful fish cultivation.

II. MATERIALS AND METHODS

2.1 HARDWARE EQUIPMENT FOR THE DEVELOPMENT OF THE SYSTEM

The proposed system is designed for fishermen to monitor water quality, ensuring a healthy environment for fish. Maintaining good water quality is crucial for aquatic life, influenced by factors such as pH levels, oxygen levels, and temperature. The system integrates various sensors to measure these parameters. Specifically, it uses a pH sensor, temperature sensor, oxygen kit, and ammonia kit to collect data from the water.

The pH sensor measures the acidity or alkalinity of the water, which is essential for fish health. Freshwater ponds typically have a pH range of 6–8. A low pH indicates acidic water, while a high pH signifies alkalinity, both of which can harm fish. Acidic conditions can affect fish reproduction, and highly alkaline water can damage their skin and eyes. Maintaining the proper pH is vital for fish survival and growth.

The system also includes a temperature sensor to monitor water temperature, as it significantly impacts fish activity and oxygen levels. Fish are more active in warmer water and require more food, while they are less active in colder water and need less food. The DS18B20 temperature sensor, which measures temperatures from −55°C to +125°C with an accuracy of ±5°C, is used in this system.

Oxygen levels are crucial for fish health. Both low and high levels of dissolved oxygen can affect water quality. Therefore, the system incorporates an oxygen kit to measure these levels, helping to manage costs effectively. Additionally, an ammonia kit is used to monitor ammonia levels, which are also critical for maintaining optimal water conditions.

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Figure 2: pH sensor

Figure 3: DS18B20 temperature sensor

Figure 4: Dissolved oxygen test kit

To measure the dissolved oxygen level in water, start by placing 5 mL of water in a jar. Add 5 drops each of test solution chemicals 1 and 2, and wait 4–5 minutes for the water to change color. The color change indicates the dissolved oxygen level, which can be compared to a color chart in the mobile application by opening the dissolved oxygen section. For measuring ammonia levels, use the ammonia kit shown in Fig. 5. Add 4 drops each of reagents 1, 2, and 3 to 2 mL of tank or pond water and wait 4–5 minutes for the water to change color. Match this color to the

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ammonia levels using the color chart provided with the kit.The ESP-12E (Fig. 6) [31] is utilized to create a wireless network connection for the microcontroller in the device.

Figure 5: Ammonia testing kits

Figure 6: ESP-12E module

The system incorporates a 32-bit internal microcontroller capable of handling multiple communications and output signals. It also includes a 12 V battery, an LM2596 buck converter for voltage regulation, a 10 kΩ resistor, a switch, and various wires. The LM2596 is used to adjust the input voltage. The NodeMCU controller features built-in Wi-Fi and connects to a pH sensor via its analog pin A0. It includes a 10-bit DC converter and a DS18B20 temperature sensor connected to the digital pin D1 of the NodeMCU, which supports 8-bit input and output. The system's development involved various types of equipment, with their names and prices listed in Tab. 1.

2.2 MIT AND GOOGLE FIREBASE

The application was developed using MIT App Inventor, which offers a user-friendly interface with a straightforward back-end setup. The software allows designers to build user interfaces using drag-and-drop functions. MIT App Inventor includes two main editors: the design editor and the blocks editor. The design editor is used for arranging UI elements, while the blocks editor allows developers to create the app's logic with color-coded blocks that fit together like puzzle pieces. This setup enables easy connection of the application to a server through an API key. To start, users can access MIT App Inventor via Google, create or sign in with a Google account, and then design the interface using various elements like text, bars, labels, and images. These elements are customized and linked across different pages to create a functional app.

III. RESULTS AND DISCUSSIONS

3.1 HARDWARE IMPLEMENTATION

Figures 10a and 10b illustrate the final prototype of the proposed system. In Figure 10a, all the equipment is interconnected and mounted on a board, with a switch controlling the power supply, which is connected to a 12V

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battery. Since a 12V input is not necessary, an LM2596 buck converter is employed to step down the voltage to 5V. This 5V is then supplied to the ESP-12E module, which begins collecting data from the pH and temperature sensors. Figure 10b depicts the real-life experiment where the data was gathered. The device was placed in a floatable bowl in a pond. As the sensors collected water data, the mobile application displayed the values. We integrated this system with our Android app and conducted an experiment at a pond to measure the pH and temperature levels of the water.

3.1.1 Result of pH Sensor

Figures 11a and 11b present the measured pH level of the water and the corresponding mobile application interface displaying the value. To measure the water's pH, a pH sensor is placed in the water, which collects the data and transmits it to the application via a Wi-Fi module. This value is then displayed in the pH section of the application. The typical pH scale ranges from 6.5 to 8.5, which is suitable for fish production. In this case, the pH value of the pond water was 7.03, making it ideal for fish cultivation. With this pH level, the water is safe and healthy for fish, allowing fishermen to cultivate fish in the pond successfully.

3.1.2 Results of Temperature Sensor

To obtain the water temperature, a temperature sensor is placed in the water. It collects the data and transmits it to the application via a Wi-Fi module. This value is then displayed in the temperature section of the application. In this experiment, the water temperature was 27.8125°C, which is suitable for fish production. The pH level of the water is also ideal, ensuring that fish remain safe and healthy. Different fish species require different temperatures, and the temperature of the water in this experiment is shown in Figure 12.

(a) (b)

Figure 10: IoT based monitoring system: (a) Shows the device, which shows the connecting equipment and (b) is the real-life experiment of the device in which the device is measuring the water of a pond

(a) (b)

Figure 11: (a) The result of pH level in water and (b) The interface of the application showing the value

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3.2 Application Development and Kit Solutions

3.2.1 Homepage

Figure 13 displays the homepage interface of the mobile application developed for the system. This homepage shows four parameters. When the user clicks on each parameter, the corresponding value or color code is displayed. For pH and temperature, the user can see the numerical values. For dissolved oxygen and dissolved ammonia, the user is provided with a color code that must be matched with the solution from the kit.

(a) (b)

Figure 12: (a) The result of water temperature and (b) The interface of the application showing the value Note: We got the value temperature was 27.8125°C. It is the standard temperature for cultivating the fish in the water body

Figure 13: Homepage interface of the application which we are using for the device

3.2.2 Results of Dissolved Oxygen Tests

To measure the dissolved oxygen, 5 ml of water was placed in a jar, and 5 drops of test solution chemical 1 and chemical 2 were added. After mixing, the solutions were left for 4–5 minutes to allow the water to change color. Once the color changed, the dissolved oxygen section in the mobile application was opened to match the water's color in the jar with the color chart in the app (Figure 14). The dissolved oxygen level was determined to be between 6–7. If the level is low, the color will be lighter, indicating a lower oxygen level.

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Figure 14: Result of dissolved oxygen (a) is the solution made by the Kit, (b) is the solution with the matching with the provided color code and (c) Shows the interface of the application of the color code

IV. CONCLUSIONS

This paper presents an IoT-based aquaculture system designed to enhance and monitor water quality in the fishing industry. The research focuses on critical parameters such as suitable temperature, pH level, oxygen supply quality, and dissolved ammonia levels. The proposed system aims to make the aquatic environment more profitable, productive, and sustainable, significantly benefiting health and the economy in Bangladesh. The government should invest in this sector, implement strict environmental policies, and facilitate effective communication between farmers, fishermen, and other stakeholders to address the growing fish demand driven by Bangladesh's booming population. Additionally, it is crucial to address factors harming the aquatic environment to ensure proper fish development.

The primary goal of this research was to secure fish health to increase fish production. To achieve this, an IoT-based fish monitoring system was developed to measure essential elements and ensure that the fish are healthy and receiving the necessary conditions for optimal growth. This system allows fisheries to monitor oxygen, ammonia, pH, and temperature levels, providing the means to maintain equilibrium. As a result, fish will grow healthier. In the future, we plan to expand the device's capabilities to check more parameters and offer the necessary equipment to maintain fish health. We also aim to educate fish farmers on proper fish health maintenance. Furthermore, we envision integrating iOS-based mobile applications with this system in the future.

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