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Monitoring Fish Farming Water Quality with IoT Sensor System

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Abstract: Aquaculture is increasingly becoming a vital component of food security and economic sustainability. However, water quality is one of the most critical factors in fish farming that directly affects the health, growth, and productivity of fish. This paper presents an innovative solution that leverages Internet of Things (IoT) technology to create a comprehensive, real-time water quality monitoring system designed specifically for aquaculture. The system integrates various sensors to track crucial water quality parameters such as temperature, pH, turbidity, and total dissolved solids (TDS), thereby ensuring optimal conditions for fish health. By offering continuous monitoring, real-time data analysis, and timely alerts, this IoT-based system enables proactive decision-making, preventing water quality degradation and increasing operational efficiency. This paper also explores the system's hardware and software architecture, working methodology, and its implications for the future of sustainable fish farming.
Keywords: IoT for aquaculture, Real-time water monitoring, Smart aquaculture, Data-driven fish farming, Sustainability in fish farming.

I. HARDWARE AND SOFTWARE REQUIREMENTS

A. Hardware Requirements

1) ESP32 Microcontroller: The core of the system, responsible for data processing and wireless communication.
2) Sensors:
   - Temperature Sensor (DS18B20): Monitors water temperature to maintain optimal thermal conditions for fish.
   - pH Sensor (SEN0161 V1.1): Measures the acidity or alkalinity of the water, ensuring it remains within safe limits.
   - Turbidity Sensor (SEN0189): Assesses water clarity by detecting the level of suspended particles.
   - TDS Sensor (SEN0244): Monitors the concentration of dissolved solids in water, an important indicator of water quality.
3) Relay Module: Controls connected devices, such as aerators or pumps, based on sensor data.

B. Software Requirements

1) Arduino IDE: An open-source platform used for programming the ESP32 microcontroller and sensors.
2) Blynk Application: A mobile-based platform for remote monitoring, providing real-time data visualization, notifications, and control features.

II. INTRODUCTION

The exponential growth in aquaculture necessitates a shift towards smarter, more efficient management practices, especially when it comes to water quality control. Maintaining the correct levels of temperature, pH, turbidity, and TDS is imperative to ensure a healthy environment for fish, but conventional methods of monitoring these parameters can be labour-intensive, time-consuming, and often inaccurate due to human error.

IoT technology offers an advanced alternative, enabling the automation of water quality monitoring through real-time data collection and analysis. By deploying sensors in fish tanks or aquaculture ponds, it is possible to continuously monitor vital water quality parameters and transmit the data wirelessly to a central platform for real-time analysis. This approach not only provides actionable insights into water conditions but also reduces the risk of fish mortality, improves fish health, and increases farm productivity.

The aim of this research is to develop an efficient IoT-based system for monitoring water quality in fish farming. By integrating real-time monitoring with automated alerts and remote access, the system addresses the challenges of traditional aquaculture management practices.

III. METHODOLOGY

A. System Framework

The overall architecture of the system consists of both hardware and software components working in tandem. As shown in Figure 1, the hardware setup includes the ESP32 microcontroller, which is connected to multiple sensors for data collection. The collected data is transmitted via Wi-Fi to the Blynk cloud server, where it is processed and stored. The Blynk application acts as the interface for the end user, allowing real-time visualization and control of the system from a smartphone or web platform.

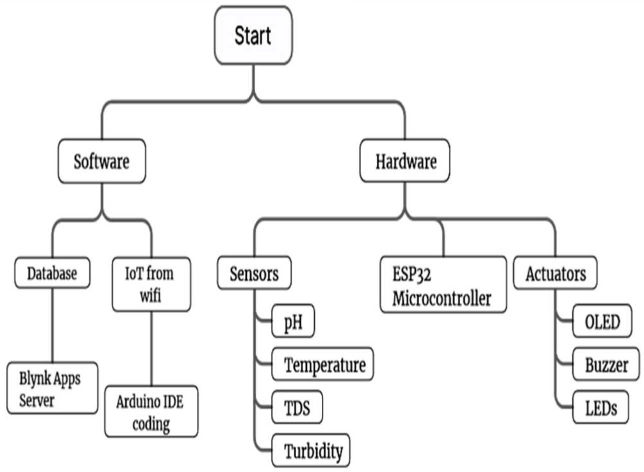

Figure 1. System Framework.

B. Hardware Integration

1) ESP32 Microcontroller: The ESP32 serves as the central processing unit, managing input from sensors and transmitting data to the cloud.
2) Temperature Sensor (DS18B20): Detects temperature fluctuations, ensuring that water remains within the ideal thermal range for fish farming.
3) pH Sensor (SEN0161): Provides continuous monitoring of the water's pH level, ensuring that the water remains neither too acidic nor too alkaline.
4) Turbidity Sensor (SEN0189): Monitors the clarity of the water by detecting the amount of suspended particles, which can affect fish health and water quality.
5) TDS Sensor (SEN0244): Measures the concentration of dissolved solids, an important indicator of water quality that can affect fish metabolism and overall pond health.

C. Software Integration

1) Arduino IDE: Responsible for programming the ESP32 microcontroller. The IDE allows for the integration of libraries necessary to establish communication between sensors and the Blynk server.
2) Blynk Application: The Blynk platform allows users to monitor and control the system remotely. Through real-time data visualization on smartphones, farmers can observe water quality trends and receive automated alerts when a parameter deviates from the pre-set range.

IV. WORKING CONCEPT

The working principle of the IoT system is centred around continuous data collection, transmission, and visualization. The sensors interface with the ESP32 microcontroller, which processes the data and uploads it to the Blynk cloud server in real-time. Figure 2 demonstrates the data flow from sensors to the cloud and back to the user’s smartphone or web dashboard.

This data can be accessed remotely through the Blynk application, allowing fish farmers to monitor key water quality parameters from anywhere. The system sends notifications or triggers automatic actions (such as turning on aerators or water pumps) if the monitored parameters exceed pre-set thresholds.

The Blynk platform also supports data export, enabling further analysis in Excel or other tools. This feature is crucial for long-term tracking and decision-making based on historical data.

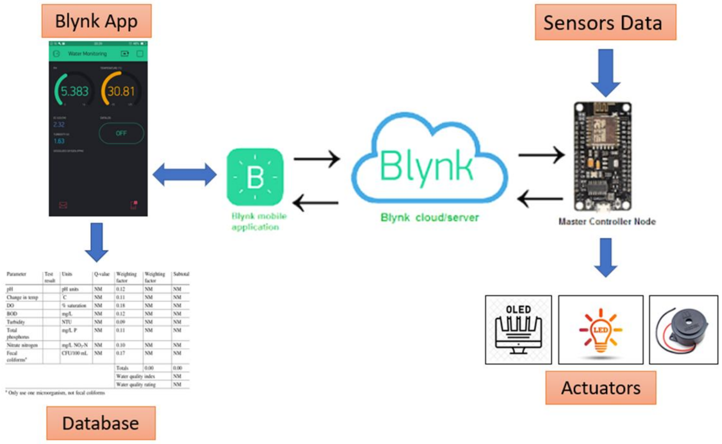

Figure 2. Working Concept.

A. Circuit Design of the System

The circuit design of the system has the components such as the temperature sensor, pH sensor, turbidity sensor, TDS sensor, buzzer, relay, OLED, resistors, and ADS1115 which are connected to the different pins on the ESP32 Module DEVKIT V1.

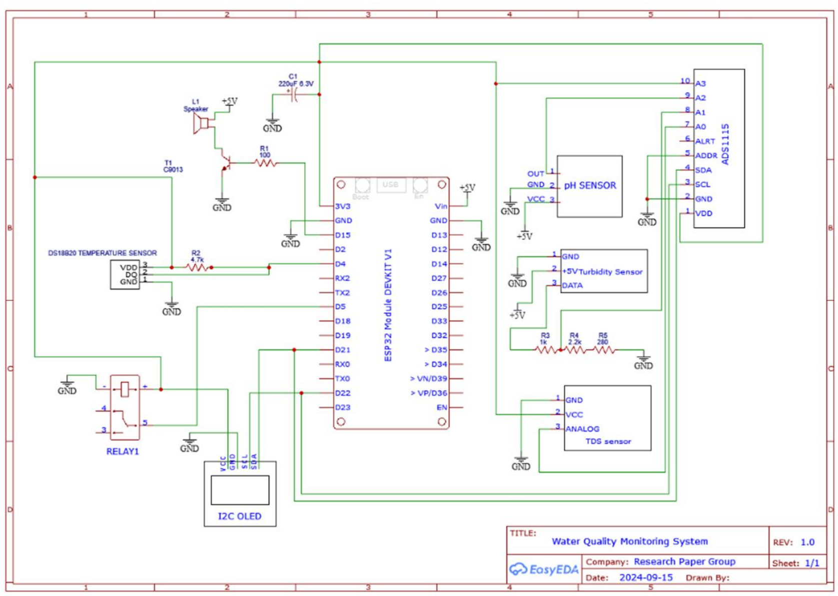

Figure 3. Circuit Design of the System.

B. Hardware Development

Each sensor plays a key role in the overall system, providing accurate readings of critical water quality parameters.

1) SEN0244 TDS Sensor: This sensor measures the concentration of total dissolved solids by detecting the water's electrical conductivity, which is influenced by dissolved ions.
2) DS18B20 Temperature Sensor: Operates on a digital interface to provide precise temperature readings, allowing for real-time monitoring of water temperature fluctuations.
3) SEN0189 Turbidity Sensor: Measures the cloudiness of water by detecting the amount of light that is scattered by particles suspended in the water.
4) SEN0161 pH Sensor: This sensor gauges the water's pH, a critical factor in maintaining a balanced aquatic environment, by converting the detected pH level into a digital signal for processing.

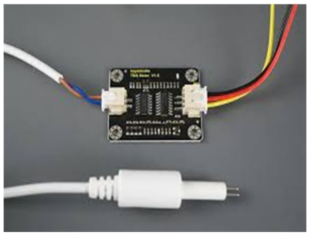

Figure 4. SEN0244 TDS Sensor.

Figure 5. DS18B20 Temperature Sensor.

Figure 6. SEN0189 Turbidity Sensor.

Figure 7. SEN0161 pH Sensor.

C. Software Implementation

The system's software is built on the Arduino IDE, an open-source platform that simplifies microcontroller programming. The Arduino environment supports the integration of libraries for ESP32 and Blynk, allowing seamless communication between sensors and the cloud. The programming language used is primarily C++, and the code controls the sensor data collection and real-time transmission. The Blynk Application serves as the user interface, connecting the ESP32 to the cloud through Wi-Fi. The Blynk platform provides real-time data visualization and control through a mobile-friendly interface. Users can monitor live data, receive alerts, and access historical data for analysis. The flexibility of the Blynk platform makes it an ideal choice for IoT-based projects like this one.

Figure 8. Arduino IDE.

Figure 9. Blynk Application.

V. LIFE EXPECTANCY OF WATER QUALITY SENSORS

These sensors are super essential for keeping aquaculture under control and catching problems early on. But over time they can lose accuracy because of stuff like slime build-up or salt damage (especially near coasts). So, we track errors closely and if they hit 20%, it's time to reset things and replace them before they mess up measurements.

A. Mathematical Formulation

Mathematical formulation can be given for percentage error in Water Quality Sensors as:

$$\%\ \text{error} = \frac{|\,Exact\ Value - Approximate\ Value\,|}{Exact\ value} \times 100$$

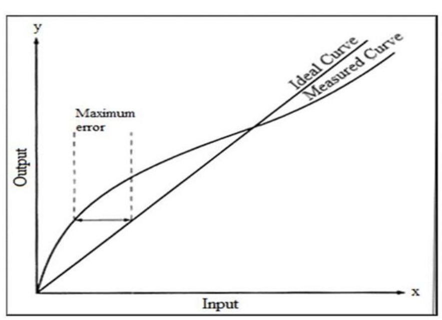

Figure 10. Characteristic Curve.

B. Observations and Data Collection

1) Ideal Range of Values

- Temperature: Consistently maintained between 22°C and 28°C, crucial for optimal fish growth.
- pH: Fluctuates within the acceptable range of 6.5 to 8.5, ideal for most freshwater fish.
- Turbidity: Values remain below 10 NTU, ensuring clear water conditions.
- TDS: Maintains an ideal range of 100 to 1000 mg/L, reflecting stable water conditions.

2) Observation Table

Water Quality Observation Table

Time	Temperature (°C)	pH	TDS (ppm)	Turbidity (NTU)
12 AM	25.8	7.6	320	5.2
2 AM	25.5	7.7	325	5.0
4 AM	25.3	7.8	328	4.8
6 AM	25.1	7.9	330	4.7
8 AM	25.4	7.7	335	5.1
10 AM	25.9	7.5	340	5.5
12 PM	26.3	7.3	345	5.8
2 PM	26.5	7.1	350	6.0
4 PM	26.7	7.0	355	6.2
6 PM	26.6	7.2	352	6.1
8 PM	26.3	7.4	348	5.9
10 PM	26.0	7.5	340	5.6
12 AM	25.7	7.6	335	5.3

Figure 11. Observation Table.

3) Graphs

Graphs can be drawn on the basis of readings written in the observation table. [Figure. 10]

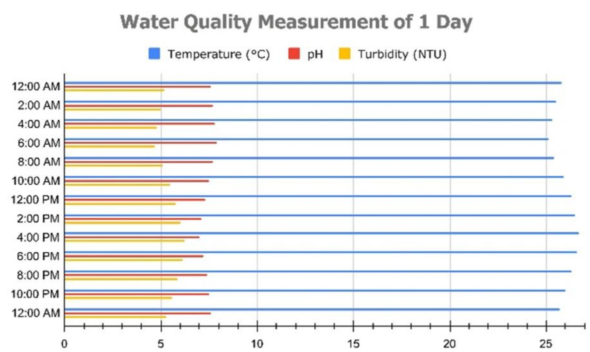

Figure 12. Graph for temperature, pH and turbidity readings.

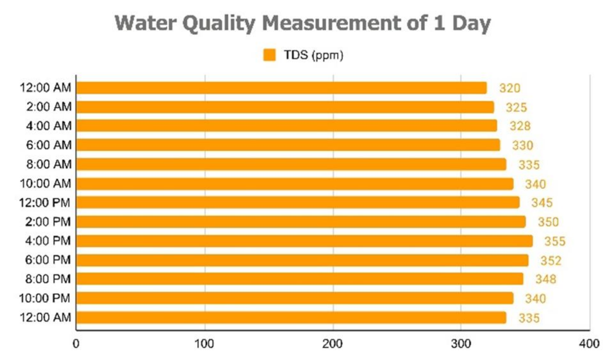

Figure 13. Graph for TDS readings.

VI. FUTURE SCOPE

The future potential of this system lies in its ability to incorporate advanced data analysis techniques to improve water quality management. Possible future developments include:

1) Time-Series Analysis: To identify seasonal trends and correlations between water quality parameters.
2) Machine Learning: Predictive models can forecast future water quality issues, allowing farmers to take preventive measures.

3) Feature Engineering: This will include deriving new variables such as temperature gradients and time-based features to improve prediction accuracy.
4) Advanced Sensor Calibration: Automated recalibration algorithms will ensure long-term sensor accuracy.

By employing machine learning and time-series forecasting models, such as ARIMA and LSTM, future versions of this system can not only monitor current water conditions but also predict future changes based on historical data, further improving decision-making for fish farmers.

VII. CONCLUSION

This IoT-based water quality monitoring system has demonstrated great potential in enhancing the management of fish farming environments. By integrating real-time data collection, remote access, and automated alerts, the system provides fish farmers with a powerful tool to maintain optimal water conditions, ultimately improving fish health and farm productivity. Although there are challenges in sensor maintenance and the complexity of water quality dynamics, ongoing research and technological advancements will continue to refine this system, making it a crucial asset in modern aquaculture.

VIII. ACKNOWLEDGEMENTS

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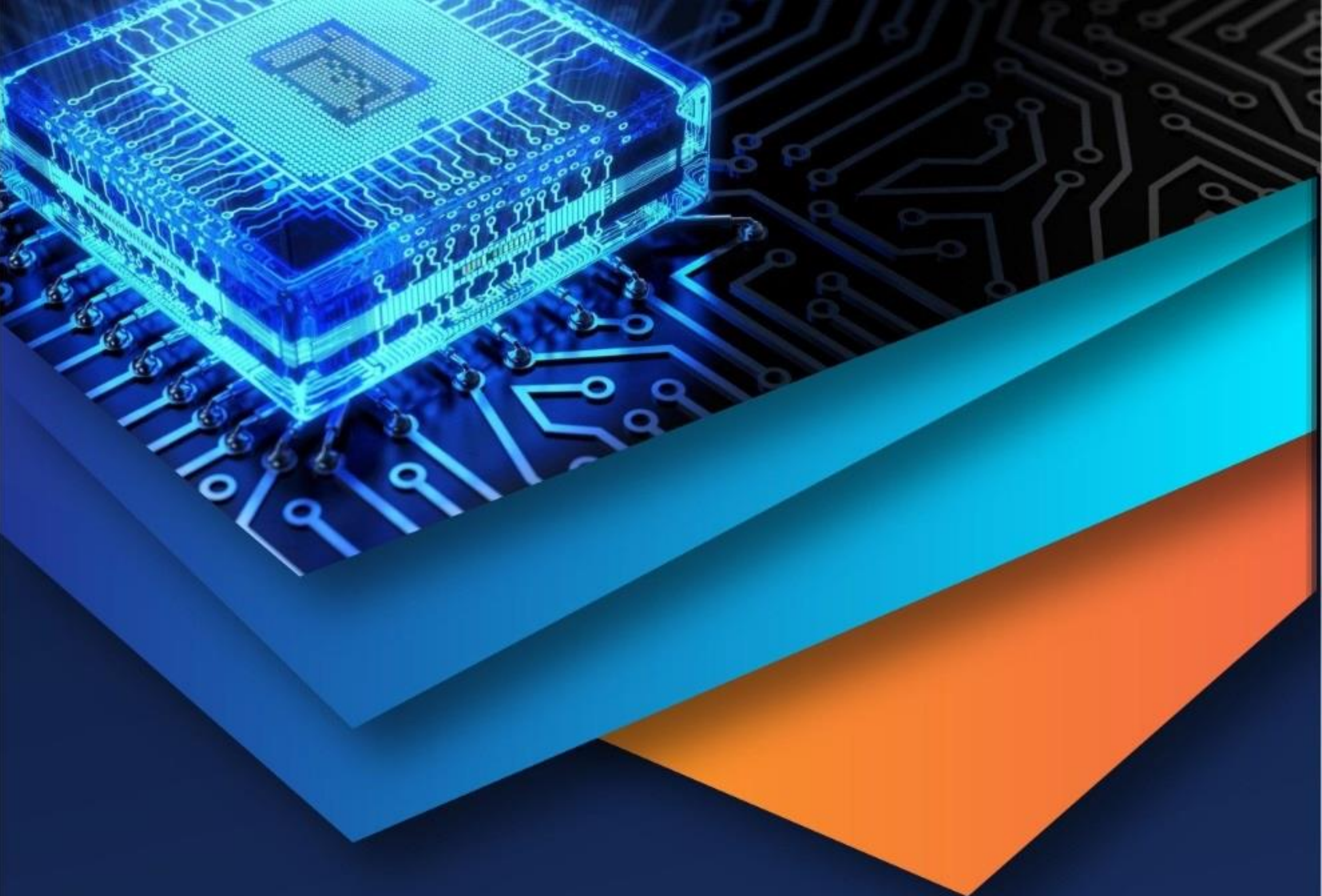

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