International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 04 | April - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Design and Development of an Intelligent IoT-Based Monitoring System for Biofloc Fish Farming Using Machine Learning

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Abstract - Aquaculture requires continuous monitoring of water quality parameters to ensure healthy fish growth and improved productivity. Traditional monitoring methods are manual, time-consuming, and unable to detect sudden environmental changes. This paper presents the design and development of an intelligent IoT-based monitoring system integrated with machine learning for biofloc fish farming. The system measures key parameters such as temperature, humidity, pH, turbidity, and total dissolved solids (TDS) using multiple sensors interfaced with an Arduino Mega microcontroller. The collected data is transmitted via the ESP8266 Wi-Fi module to an IoT cloud platform for real-time monitoring and visualization. A Random Forest algorithm is employed to analyze the data and predict abnormal water conditions. Based on the analysis, an automated relay mechanism activates a water pump to maintain optimal water quality. The proposed system improves efficiency, reduces manual effort, enables predictive decision-making, and enhances overall productivity in aquaculture systems.

Key Words: IoT-Based Monitoring, Biofloc Fish Farming, Arduino Mega, ESP8266, Water Quality Sensors, Machine Learning, Random Forest, Aquaculture Automation

1.INTRODUCTION

Aquaculture has become an essential sector for meeting the increasing global demand for protein-rich food. Among various techniques, biofloc fish farming is gaining popularity due to its sustainability and efficient resource utilization. However, maintaining optimal water quality remains a critical challenge, as parameters such as temperature, pH, turbidity, and total dissolved solids (TDS) directly affect fish health, growth, and survival. Traditional monitoring methods are manual and inefficient, failing to detect sudden environmental changes and often leading to poor water conditions and reduced productivity. The integration of Internet of Things (IoT) technology enables continuous monitoring and real-time data acquisition using sensor networks and cloud platforms. However, most existing IoT-based systems lack predictive analysis and automated control mechanisms. To address this limitation, this paper proposes an intelligent IoT-based monitoring system integrated with machine learning for biofloc fish farming. The system uses multiple sensors interfaced with an Arduino Mega microcontroller, with data transmitted via an ESP8266 Wi-Fi module to a cloud platform. ABSTRACT A Random Forest algorithm is employed to predict abnormal conditions, and an automated relay mechanism controls a water pump to maintain optimal water quality. The proposed system improves efficiency, reduces manual effort, and enhances overall productivity in aquaculture.

2. RELATED WORK

Several IoT-based systems have been proposed for monitoring water quality in aquaculture environments. These systems typically employ sensors to measure parameters such as temperature, pH, turbidity, and dissolved oxygen, with data transmitted to cloud platforms for real-time monitoring and visualization. Some studies also incorporate basic automation mechanisms to control water circulation and aeration. However, most existing systems are limited to real-time monitoring and lack predictive capabilities based on historical data analysis. They often rely on manual decision-making, which can delay corrective actions and affect fish health. In addition, many systems monitor only a limited set of parameters, reducing their effectiveness in maintaining optimal water conditions. Furthermore, issues such as lack of scalability, higher operational costs, and limited integration with intelligent decision-making techniques reduce their practical applicability in large-scale aquaculture systems.

Recent advancements have explored data analytics and machine learning techniques, but their adoption is limited due to complexity and high computational demands. To address this, the proposed system integrates machine learning with IoT for predictive analysis and automated control, improving efficiency, reliability, and sustainability in biofloc fish farming.

3. PROPOSED SYSTEM

The proposed system is an intelligent IoT-based monitoring system designed for biofloc fish farming to ensure optimal water quality. The system integrates multiple sensors, a microcontroller, wireless communication, and machine learning for real-time monitoring and automated control. The overall architecture of the proposed system is shown in Fig. 1.

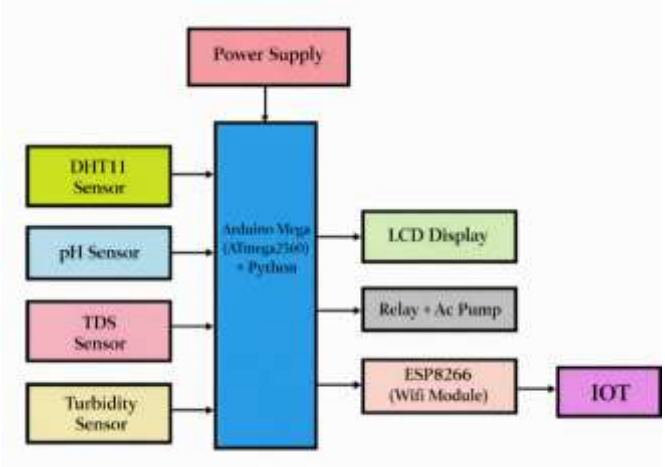

Fig. 1. Block Diagram of Proposed IoT-Based Biofloc Monitoring System

The system uses sensors such as DHT11, pH, turbidity, and TDS to measure key water quality parameters including temperature, humidity, acidity, dissolved solids, and water clarity. These sensors are interfaced with an Arduino Mega microcontroller, which processes the collected data.

The processed data is transmitted to an IoT cloud platform using the ESP8266 Wi-Fi module, enabling real-time monitoring and remote access. A Random Forest machine learning algorithm is used to analyze the sensor data and predict abnormal water conditions.

Based on the prediction results, an automated control mechanism is implemented using a relay module to activate an AC water pump when parameters exceed predefined threshold values. This helps maintain optimal environmental conditions for fish growth and improves overall system efficiency.

Advantages of the Proposed System:

- Enables real-time monitoring of multiple water quality parameters
- Reduces manual effort and human errors
- Provides predictive analysis using machine learning
- Supports automated control through relay-based actuation
- Improves fish health and overall productivity
- Cost-effective and scalable for small and large farms

4. METHODOLOGY

The proposed system operates through a sequence of data acquisition, processing, analysis, and control. Initially, sensors such as DHT11, pH, turbidity, and TDS continuously monitor water quality parameters including temperature, humidity, acidity, dissolved solids, and water clarity.

The collected sensor data is processed by the Arduino Mega microcontroller, which acts as the central control unit. The processed data is then transmitted to an IoT cloud platform through the ESP8266 Wi-Fi module, enabling real-time monitoring and visualization.

The received data is analyzed using a Random Forest machine learning algorithm to detect abnormal water conditions. Based on the analysis, if any parameter exceeds predefined threshold values, a relay module is activated to control an AC water pump for water circulation and aeration.

This automated process ensures continuous monitoring, predictive analysis, and immediate corrective action, thereby maintaining optimal water quality and improving efficiency in biofloc fish farming.

5. RESULTS AND DISCUSSION

The proposed IoT-based monitoring system was successfully implemented for real-time monitoring of water quality parameters in a biofloc fish farming setup. The system continuously measures temperature, humidity, pH, turbidity, and total dissolved solids (TDS) using integrated sensors. The acquired data is processed by the Arduino Mega microcontroller and transmitted to the cloud through the ESP8266 module for real-time

access and visualization. The system ensures continuous observation of environmental conditions and provides timely updates for effective monitoring. This enables early detection of parameter variations, helping maintain optimal water quality for healthy fish growth.

The experimental results indicate that the system provides stable and reliable sensor readings under varying environmental conditions. The integration of machine learning allows effective prediction of abnormal water quality levels, enabling proactive decision-making. The automated relay mechanism responds promptly to threshold variations, ensuring immediate corrective action. Overall, the system demonstrates improved efficiency, reduced manual intervention, and enhanced reliability in aquaculture monitoring.

Fig. 2 shows the hardware implementation of the proposed system, where sensors are interfaced with the Arduino Mega microcontroller and connected to the ESP8266 module for wireless communication. The system was tested under different environmental conditions, and the sensor readings were observed to be stable and responsive to variations in water quality parameters.

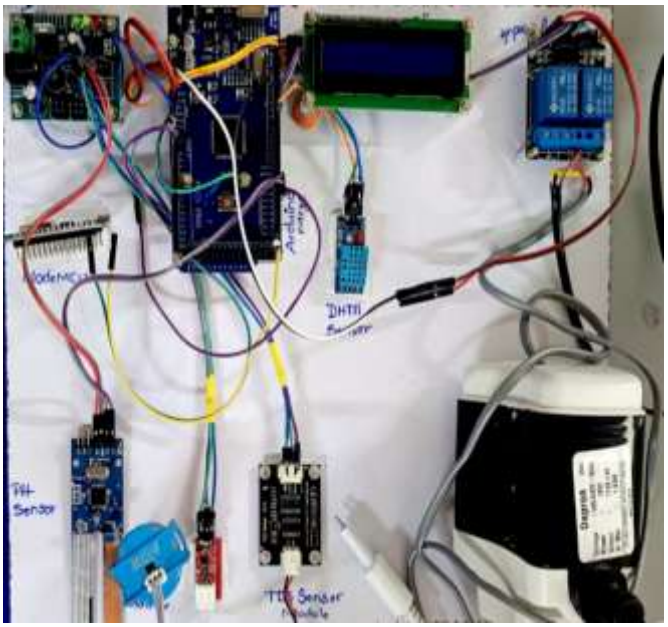

Fig. 2. Hardware Implementation of the Proposed System

The collected data is transmitted to an IoT cloud platform, enabling real-time monitoring and visualization of parameters. The real-time visualization of water quality parameters is shown in Fig. 3.

Fig. 3. IoT Cloud Visualization of Water Quality Parameters

Applications:

- Biofloc fish farming systems for real-time water quality monitoring
- Aquaculture ponds and hatcheries for maintaining optimal environmental conditions
- Smart agriculture systems requiring water quality management
- Environmental monitoring of lakes, tanks, and reservoirs
- IoT-based automation systems for remote monitoring and control

Limitations:

- The system does not include dissolved oxygen monitoring, which is a crucial parameter in aquaculture.
- Continuous internet connectivity is required for real-time data transmission and monitoring.
- The accuracy of the Random Forest algorithm depends on the quality and quantity of training data.
- Sensor readings may be affected by calibration errors and long-term usage.
- Initial setup and maintenance costs may be a challenge for small-scale farmers.

6. FUTURE SCOPE AND CONCLUSION

This paper presents an intelligent IoT-based monitoring system integrated with machine learning for biofloc fish farming. The system enables real-time monitoring of water quality parameters such as temperature, pH, turbidity, and total dissolved solids using multiple sensors interfaced with an Arduino Mega microcontroller. The integration of the ESP8266 module allows continuous data transmission to a cloud platform for remote monitoring and visualization.

The implementation of the Random Forest algorithm provides effective analysis of sensor data and enables early detection of abnormal conditions. The automated relay mechanism ensures timely corrective action by activating the water pump, thereby maintaining optimal water quality and supporting healthy fish growth.

The proposed system improves monitoring efficiency, reduces manual effort, and enhances decision-making in aquaculture management. Future work may focus on integrating additional sensors such as dissolved oxygen, developing mobile-based monitoring applications, and implementing advanced machine learning models for improved prediction accuracy and scalability.

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