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Intelligent Aquarium Habitat Monitoring And Maintenance System

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Abstract: The Intelligent Aquarium Monitoring and Maintenance System is a smart and automated solution developed to maintain optimal environmental conditions in aquariums. Aquatic life is highly sensitive to changes in water quality parameters such as temperature, pH, turbidity, and water level. Even slight deviations from ideal conditions can result in stress, disease, or death of fish and other organisms.This system integrates multiple sensors with an ESP32 microcontroller to continuously monitor these parameters in real time. Based on the collected data, automated control mechanisms such as feeding systems, water pumps, filtration units, and cooling devices are activated. The system is further enhanced with Internet of Things (IoT) technology, enabling remote monitoring and control via mobile or web applications. The proposed system significantly reduces human effort, minimizes errors, and ensures timely corrective actions. It provides a cost-effective and scalable solution for both domestic aquariums and commercial aquaculture systems, ensuring improved aquatic health and system reliability.

I. INTRODUCTION

Aquariums are artificial aquatic ecosystems that require careful monitoring and maintenance to ensure the survival and well-being of aquatic organisms such as fish, plants, and microorganisms. Unlike natural water bodies, aquariums are closed environments where external factors cannot easily regulate internal conditions. Therefore, maintaining optimal water quality parameters is essential for sustaining a healthy ecosystem. Key environmental parameters such as temperature, pH level, turbidity, dissolved oxygen, and water level play a significant role in determining the health of aquatic life. Even minor fluctuations in these parameters can lead to stress, disease, and in severe cases, death of fish and other organisms. For example, an increase in water temperature reduces oxygen solubility, while improper pH levels can affect metabolic activities of aquatic species. Hence, continuous monitoring and timely corrective actions are crucial for maintaining stability in aquarium conditionsTraditionally, aquarium maintenance is performed manually, which involves periodic checking of water parameters and manual operation of equipment such as heaters, filters, and feeders. While this approach may be suitable for small-scale aquariums, it becomes inefficient and unreliable as the size and complexity of the system increase. Manual monitoring is time-consuming and prone to human errors, such as delayed responses, inaccurate measurements, and inconsistent maintenance practices. Additionally, it is not feasible to monitor the aquarium continuously, especially during night hours or when the user is away. With the advancement of technology, particularly in the fields of embedded systems and the Internet of Things (IoT), it has become possible to develop intelligent systems that can automate monitoring and control processes. IoT enables real-time data acquisition, analysis, and communication, allowing devices to interact with each other and with users remotely. This technology has been widely applied in various domains such as smart homes, healthcare, agriculture, and environmental monitoring. In the context of aquaculture, IoT-based

solutions provide a promising approach to overcome the limitations of traditional methods. By integrating sensors, microcontrollers, and communication modules, it is possible to design a system that continuously monitors environmental parameters and automatically takes corrective actions when necessary. Such systems not only improve efficiency but also ensure consistency and reliability in maintaining optimal conditions. The proposed Intelligent Aquarium Monitoring and Maintenance System leverages IoT and embedded technologies to provide a comprehensive solution for aquarium management. The system uses sensors to measure key parameters such as temperature, pH, turbidity, and water level. These sensors are connected to an ESP32 microcontroller, which acts as the central processing unit. The ESP32 processes the sensor data and compares it with predefined threshold values to determine whether the conditions are within acceptable limits. When a parameter exceeds its threshold, the system automatically activates the corresponding control mechanism. For instance, if the temperature rises above the desired range, a cooling fan or temperature control system is activated. Similarly, if the water becomes turbid, the filtration system is triggered to clean the water. The system also includes an automated feeding mechanism that ensures fish are fed at regular intervals, thereby eliminating the need for manual feeding. Another important feature of the system is its ability to provide remote monitoring and control through IoT platforms. Users can access real-time data from the aquarium using a smartphone or computer, allowing them to monitor conditions from anywhere at any time. Alerts and notifications can also be generated when parameters exceed safe limits, enabling users to take immediate action if required. The integration of automation and IoT not only enhances the efficiency of aquarium maintenance but also improves the overall quality of life for aquatic organisms. By reducing human intervention and ensuring continuous monitoring, the system minimizes the risk of sudden environmental changes and provides a stable habitat for aquatic life.

II. LITERATURE SURVEY

In recent years, several researchers have proposed various IoT-based aquarium monitoring and control systems to improve aquatic environment management. These studies highlight the evolution of smart aquarium systems from basic monitoring to advanced automation and intelligent control.

In 2021, A. Asokan, D. K. M., and Shanmugapriya developed a real-time smart aquarium monitoring system using IoT technology. Their system focused on monitoring key parameters such as temperature and pH levels. The collected data was transmitted to a mobile application, enabling users to receive alerts and notifications. Although the system provided effective real-time monitoring, it primarily focused on observation and lacked advanced automation features for corrective actions.

In 2022, R. Kumar, P. Singh, and L. Verma proposed the design and implementation of an IoT-based smart aquarium system using the ESP32 microcontroller. Their system integrated sensors such as pH, temperature, and turbidity sensors, along with an automatic feeding mechanism. The system provided real-time monitoring and partial automation; however, it lacked intelligent decision-making capabilities and advanced control mechanisms, limiting its efficiency in maintaining optimal conditions.

Further advancements were observed in 2023, when S. Chen, Y. Wang, and D. Liu introduced an IoT-enabled intelligent aquaculture monitoring and control system. This system was designed for large-scale aquaculture applications and included automated pumps and aerators. It also utilized cloud-based data storage for monitoring and analysis. While the system demonstrated effective automation and scalability, it was primarily focused on large-scale operations and was not optimized for small or medium-scale aquarium systems.

In 2024, H. Rahman, M. Islam, and A. Hossain developed a smart aquarium system that combined automatic feeding, turbidity-based filtration, and temperature control. Their system operated based on predefined threshold values, ensuring timely activation of actuators. Although the system improved automation, it still relied on fixed thresholds and lacked adaptability to dynamic environmental changes.

More recently, in 2025, L. Zhang, Q. Li, and T. Huang proposed an AI-based smart fish tank monitoring system using IoT. Their system incorporated machine learning techniques to predict fish health and autoamatically adjust environmental conditions. It also integrated cloud analytics for advanced data

processing and adaptive habitat management. Despite its advanced features, the system involved higher complexity and cost, making it less accessible for general users.

From the above studies, it is evident that significant progress has been made in the development of smart aquarium systems. However, existing solutions still face limitations such as lack of full integration, high implementation cost, dependency on predefined thresholds, and limited accessibility for small-scale users.EXISTING SYSTEM

The current system is that the customer needs to ask for the contact details of the shopkeeper to share the documents in order to get a hard copy of the shared documents. However, this method will expose the contact details and information of both the customer and the shopkeeper. The shopkeeper will get confused with a lot of files that are shared by the various customers. The disadvantage of the existing system is that the contact details got exposed, which has the possibility of being misused.

III. PROPOSED SYSTEM

The proposed Intelligent Aquarium Monitoring and Maintenance System is designed as a fully automated and IoT-enabled solution to ensure optimal environmental conditions within an aquarium. The system integrates multiple sensors, including temperature, pH, turbidity, and water level sensors, which continuously monitor the physical and chemical parameters of the water in real time. These sensors are interfaced with an ESP32 microcontroller, which acts as the central processing unit responsible for data acquisition, analysis, and decision-making. The collected sensor data is compared with predefined threshold values, and whenever any parameter deviates from the acceptable range, the system automatically triggers appropriate control actions through actuators such as a water pump, filtration unit, cooling fan, and servo motor for fish feeding. In addition to automation, the system incorporates Internet of Things (IoT) technology to enable remote monitoring and control, allowing users to access real-time data, receive alerts, and manage system operations through a mobile or web-based interface. The integration of monitoring, control, and communication ensures continuous supervision of aquarium conditions without human intervention, thereby reducing manual effort and minimizing the risk of sudden environmental changes. Compared to existing systems, the proposed model provides a cost-effective, scalable, and user-friendly approach by combining real-time sensing, automatic response mechanisms, and remote accessibility into a single unified platform, making it suitable for both small-scale domestic aquariums and larger aquaculture applications.

Features

- Real-time monitoring of temperature, pH level, turbidity, and water level using sensors
- Automatic activation of devices like water pump, filter, cooling fan, and feeder based on sensor readings
- Remote monitoring and control through IoT using mobile or web applications
- Automated fish feeding system using a servo motor at scheduled intervals
- Continuous maintenance of water quality through filtration and purification mechanisms.

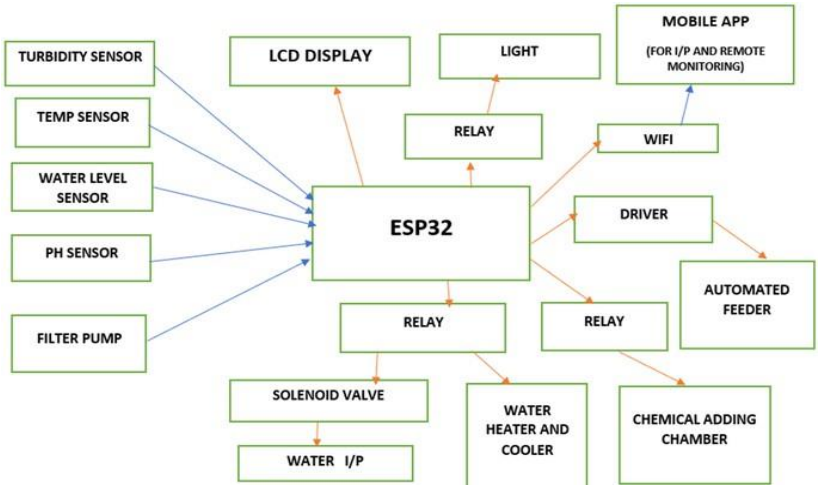


Fig. 1 : Overall System Architecture of the proposed system

IV. RESULTS AND DISCUSSION

The proposed Intelligent Aquarium Monitoring and Maintenance System was tested under different conditions to evaluate its performance. The system successfully monitored parameters such as temperature, pH, turbidity, and water level in real time. The ESP32 processed sensor data efficiently and activated control mechanisms when thresholds were exceeded. The cooling system, filtration unit, and water pump operated automatically to maintain optimal conditions. The automated feeding system ensured timely and consistent feeding of fish. IoT integration enabled remote monitoring and alert notifications for users. The system reduced manual effort and improved response time to environmental changes. Overall, the results demonstrate that the system is reliable, efficient, and suitable for smart aquarium management.

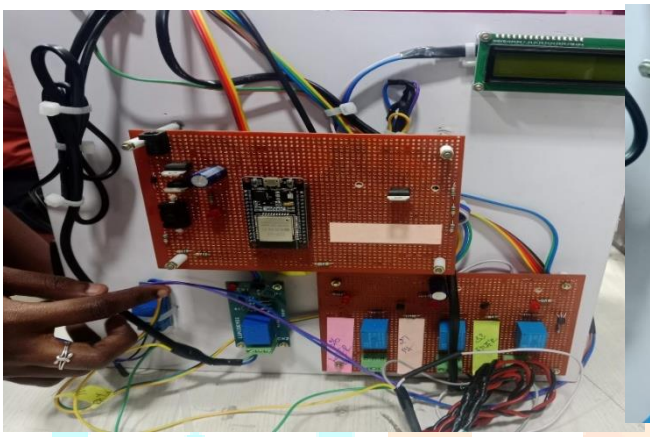


Fig 2 : Hardware setup back view

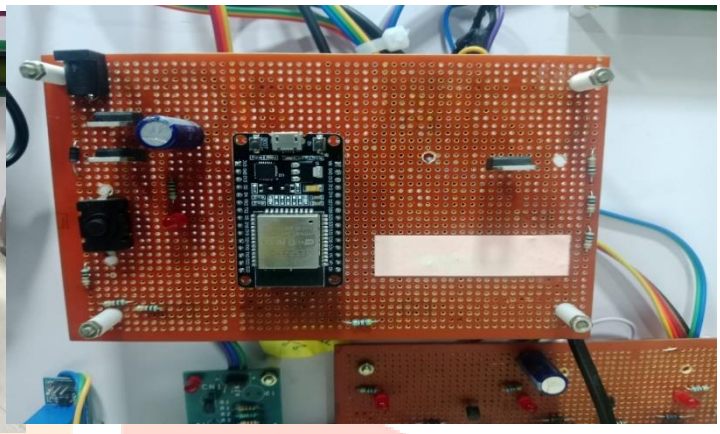
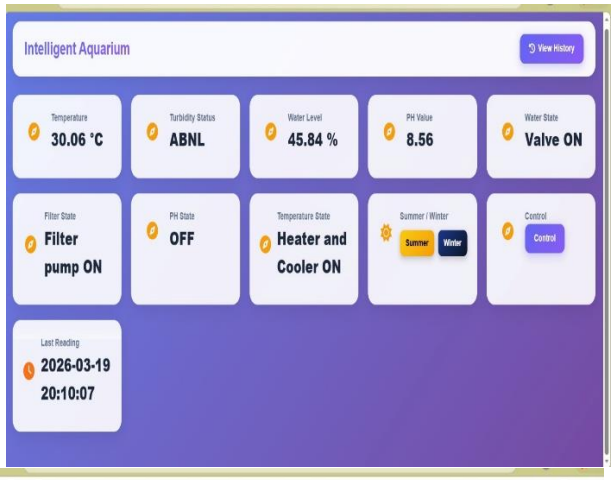


Fig 3 : Hardware setup

Fig. 2 shows the front view of the hardware setup of the system. Fig. 3 shows the hardware setup of the system

Fig 4 : Hardware setup front view

Fig. 4 shows the front view of the hardware setup. Fig. 6 shows the web dashboard created for the system. Fig. 7 shows the history of the system conditions. Fig. 8 shows the LCD Display with values of the system.



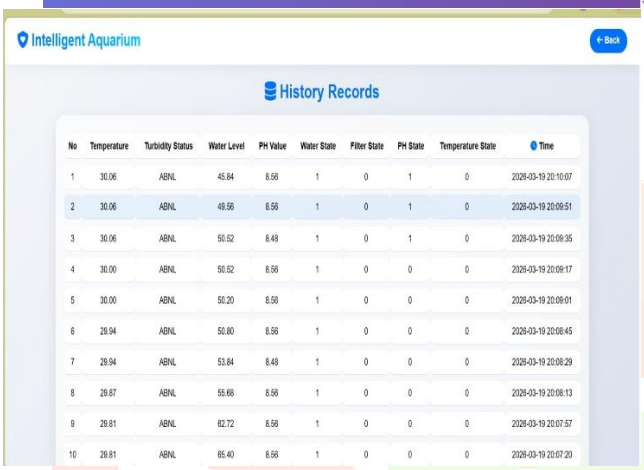


Fig 6 : Web dashboard Fig 7 : Dashboard History

Fig 8 : LCD Display

IV. CONCLUSION

The Intelligent Aquarium Monitoring and Maintenance System provides an efficient and automated solution for maintaining optimal conditions in an aquarium. By integrating sensors, an ESP32 microcontroller, and IoT technology, the system ensures continuous monitoring and control of key water parameters such as temperature, pH, turbidity, and water level. The automation of feeding, filtration, and temperature regulation reduces manual effort and minimizes human error. The IoT-based remote monitoring feature enhances user convenience by providing real-time data and alerts. The system demonstrates high reliability and effectiveness in maintaining a stable aquatic environment. Overall, it offers a cost-effective and practical solution for both domestic and commercial aquarium applications.

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