AquaSmart: IoT Innovations in Fish Tank Management

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***Abstract*—Aquarium maintenance requires constant monitoring of environmental factors such as feeding schedules, water condition, and temperature, to ensure the health of aquatic life. However, these tasks are often time consuming and can be prone to human error, affecting the health of fish. This paper introduces Aquasmart, an IoT-based solution designed automate and optimize aquarium care in a manner that increases the ease of maintaining it. The system uses automated feeding and lighting, along with real-time health monitoring using pH and temperature sensors, providing a robust structure for maintaining ideal water conditions. Additionally, Aquasmart features an automated oxygenation system with an integrated oxygen pump that ensures proper oxygen flow into the aquarium, helping maintain a healthy environment for aquatic species. The system also sends notifications to the user when predefined thresholds are violated, prompting timely actions such as water changes. Aquasmart also incorporates adaptive cooling, which becomes active when the temperature limits are breached, ensuring a stable aquatic environment. This paper presents the system design and performance that demonstrates the effectiveness of Aquasmart as an easy-to-use tool in facilitating a controlled, healthy aquatic environment through IoT-driven automation.**

***Index Terms*—Internet of Things (IoT), Aquarium, Automation, pH sensors, Oxygenation system, Temperature sensor.**

I. INTRODUCTION

Aquariums add beauty and a sense of calm to homes and workplaces, but keeping fish healthy requires consistent attention to their environment. Factors such as water temperature, pH balance, oxygen levels, and feeding routines must stay within the right range, or fish can quickly become stressed or ill.

Fluctuating temperature or improper pH can irritate a fish's skin and gills, weaken immunity, and in severe cases lead to death. Overfeeding is another common issue, as excess food decays and increases toxins like ammonia and nitrates, while underfeeding can result in poor growth and vulnerability to disease. Poor water quality, inadequate filtration, and low oxygen levels further worsen the tank's condition, often leading to cloudy water, algae growth, and an unhealthy habitat.

These challenges make regular monitoring essential for maintaining a stable environment. With the rise of Internet of Things (IoT) technology, aquarium care can now be supported with automated systems that track water quality, regulate temperature, and manage feeding in real time. Such smart solutions reduce manual effort while improving the consistency and overall health of the aquatic ecosystem.

As aquariums become more common in households and small businesses, the need for reliable and easy-to-use monitoring systems continues to grow. Many owners lack the time or technical knowledge to perform frequent checks, making automation a practical and effective approach. IoT-based systems offer an accessible way to maintain ideal conditions, ensuring both convenience for users and a safer, more stable environment for aquatic life.

II. LITERATURE SURVEY

Recent IoT-based aquarium systems have greatly enhanced automation and remote monitoring for aquatic environments. Mohd Daud et al. (2020) built a system to monitor pH, temperature, and ammonia, with real-time adjustments and mobile-based control [1]. Liu et al. (2021) created a smart marine tank that tracks temperature, salinity, and pH, offering notifications and remote management via an app [2]. Abu-Khadrah et al. (2022) automated feeding and environmental monitoring using cloud-based control for reduced manual intervention [3]. Jain et al. (2019) integrated cloud connectivity for continuous tracking

of key water parameters and automatic environmental adjustments [4].

Theagarajan et al. (2023) developed an IoT-enabled tank with automated filters and heaters for improved efficiency and user convenience [5]. Hao et al. (2020) designed a cloud-supported intelligent tank to monitor and control temperature and dissolved oxygen remotely [6]. Singh and Kumar (2019) reviewed IoT systems in aquariums, noting challenges in reliability and suggesting predictive analytics and energy-efficient solutions [7]. Sharma and Gupta (2021) introduced an Arduino-IoT aquaculture system with automatic feeding and cloud-based monitoring of water quality [8]. Overall, IoT offers improved stability and real-time control in aquariums, but future work is needed in sensor accuracy, data processing, and advanced machine learning for smarter decision-making.

III. PROBLEM STATEMENT

Maintaining a healthy and balanced environment in an aquarium is essential for the well-being of aquatic life, but it requires constant monitoring and manual interventions that can be time-consuming and complex. Key parameters like ammonia, pH, and temperature must be carefully regulated to prevent harmful water conditions, while timely oxygenation, feeding, and lighting adjustments are crucial to support optimal fish health and reduce stress. Current aquarium management solutions often lack comprehensive monitoring and real-time alert systems, leaving aquarium owners with limited information on water quality and increasing the likelihood of overfeeding, inadequate oxygen levels, and unchecked changes in water chemistry.

There is a need for an intelligent, automated system that provides continuous health monitoring and user-friendly control over essential aquarium functions. This system should seamlessly integrate sensors to track ammonia, pH, and temperature, coupled with an oxygen pump, automatic lighting, cooling mechanisms, and a controlled feeding setup to provide a proactive, efficient, and comprehensive aquarium management solution. Such a system would enable aquarium owners to maintain optimal water quality and support fish health with minimal manual effort, ensuring a sustainable and healthy aquatic environment.

IV. PROPOSED SYSTEM

Our IoT-based smart aquarium system redefines aquarium care by integrating advanced monitoring and control mechanisms focused on both environmental and health parameters. At the core of this system is a comprehensive health monitoring suite, which includes sensors for pH and temperature. Together, these sensors provide continuous insights into water quality, a critical factor for maintaining a healthy aquatic environment. The pH and temperature sensors further support water quality assessment, contributing to an early warning system that notifies users when cleaning or maintenance is required.

In addition, our system includes an oxygen pump that supplies extra oxygen when needed, ensuring that oxygen levels remain suitable for aquatic life, particularly in densely populated tanks. Automatic lighting enhances the natural day- night cycle, reducing fish stress, while the system's cooling fan activates when water temperature exceeds 28°C, maintaining an optimal temperature range. Feeding is made both convenient and controlled through a manual notification-based system: users receive alerts when feeding time arrives and can dispense food with a single button press, preventing overfeeding and supporting a balanced diet for the fish.

V. METHODOLOGY

A. System Overview:

The key features of this system will be smart feeding, smart lighting, smart cooling, and water monitoring, ensuring optimal health of fish and user convenience.

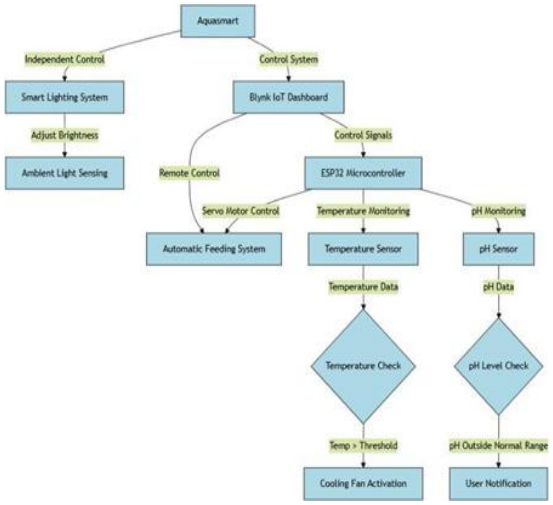

Fig. 1. System Overview

The ESP32 microcontroller is at the heart of the system, which acts as a managing center for all key functionalities:

- Smart Feeding Mechanism: Dispenses food at precise times to provide the right nutrition for the animal and minimize waste.
- Smart Cooling System: Smart System monitors water temperature and activates cooling elements for a comfortable aquatic ecosystem.
- The Water Monitoring System is consistent in tracking parameters such as the pH levels and water temperature, sending instant alerts for when maintenance or corrective action may be required.
- Oxygen Pump Control: maintains water oxygen levels and will alert users when oxygen levels become insufficient for the fish
- Smart Lighting Circuit: works independently from the ESP32 board, uses an LDR sensor to adjust automatically according to ambient light conditions to simulate a day night light cycle that will help not stress the fish.

The information from the sensors is transmitted wirelessly to an IoT platform, allowing for monitoring and adjustment of the system over a distance. The user interface on the smartphone or computer facilitates convenient access to real time updates and adjustments.

B. Components Used for the Fish Tank System:

In the "Aquasmart" system, the central processing unit is the ESP32 microcontroller that will receive, process, and transmit data. The system integrates several sensors and actuators to automate management processes in a fish tank. Below is the detailed component-level description:

Input Sensors:

- pH Sensor: to ensure there is proper pH of water, making it safe to the aquatic environment for the fish.
- Temperature Sensor: Ascertains the water temperature to avoid conditions that can harm the health of the fish.
- LDR Sensor (Lighting Module) – Independently controls lighting based on ambient light levels

Actuators:

- Servo Motor (Feeding Mechanism): Dispenses food at scheduled intervals, so the fish will get accurate portions.
- Oxygen Pump: Adjusts the level of oxygen in the water automatically with inputs from the sensor, keeping it at an optimal state.
- Cooling Unit: Enabling of which lowers the water temperature when it crosses the set threshold.

Cloud Connectivity:

- ESP32 sends real-time data to the IoT platform via Wi-Fi for remote monitoring and control.
- Blynk app Notifications: Alerts are generated for abnormal pH, temperature, or oxygen levels, allowing timely user action.

The ESP32 microcontroller acts as the brain of the system, processing input data from the sensors and triggering appropriate responses in the actuators. The LDR-controlled lighting and IoT-based monitoring system work in parallel to enhance user convenience and improve the fish tank's ecosystem.

C. Features

There are two main functionality divisions of the system: Independent Control and Centralized Control using the ESP32 Microcontroller. Below are the detailed descriptions of the operation for each subsystem, with an added theory for the oxygen pump.

1. Independent Control:

Smart Lighting System: The Smart Lighting System is independent in operating by changing the brightness of the light inside the tank due to light 4 conditions.

Ambient Light Sensing: The LDR sensor measures the ambient light level and consequently adjusts the brightness levels of the lights in the fish tank to give the fish a natural day-night cycle.

2. Control System Centralized:

A control center is provided by the ESP32 microcontroller connected to Blynk's IoT dashboard, which handles all sensors and actuators, in terms of the reading and automatic feeding process, temperature, and pH levels.

Automatic Feeding System: As shown in Fig 2. the system utilizes a servo motor to dispense fish food at predetermined times or based on a signal sent over the internet by the user using an IoT dashboard. That way,

the fish are sure to receive adequate feeding `without any human interference.

Fig. 2. Feeding system flowchart

pH Monitoring and Alert: pH sensor measures the acidity or alkalinity of water.
Logic: As shown in Fig 3. Logic is such that if the pH level gets out of the normal range (6.5–8.0), then the system gives an alert from the Blynk IoT dashboard to the user to take corrective measures.

Temperature Monitoring and Control: The water temperature is constantly checked using a temperature sensor and the data it collects is passed onto the ESP32 microcontroller.

Logic: Once the temperature crosses the threshold, the cooling fan comes ON, which lowers the water temperature. This maintains the temperature within the optimal parameters for fish.

Cooling System: A DS18B20 or comparable temperature sensor constantly follows the water temperature. It transmits real-time temperature readings to the ESP32 microcontroller. A cooling fan is used to dissipate heat and reduce the water temperature; in case it exceeds a specified threshold. The relay module controls the fan, and is connected to the ESP32 microcontroller.

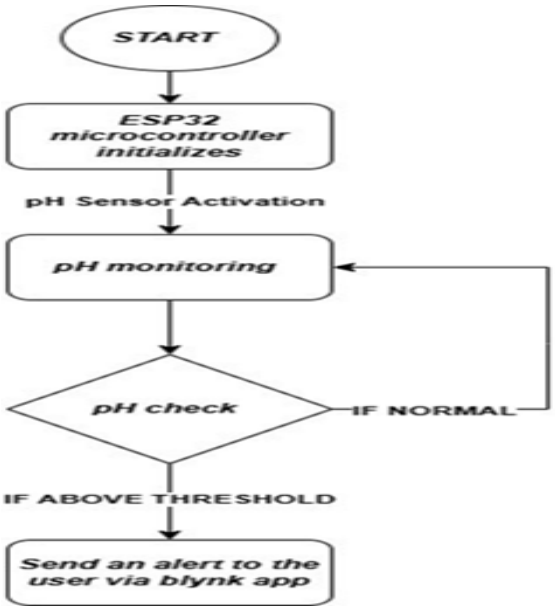

Fig. 3. pH monitoring flowchart

Logic: As shown in Fig 4. The system constantly checks the water temperature against the required threshold value (e.g., 25°C for tropical fishes). Once the temperature comes to within the desired level, there is nothing to be done. Once the water temperature has exceeded the given threshold value then the ESP32 microcontroller switches the relay that activates the cooling fan. The fan works to cool the water, probably by increasing convection of air around the tank, or by blowing across the surface of the water to cool it through evaporation, which cools the water. Once the temperature comes back to the safe range the ESP32 turns off the fan to conserve energy and keep a stable environment for the fish.

Fig. 4. Cooling system flowchart

Oxygen Pump: The oxygen pump maintains adequate oxygen levels in the water, which is necessary for the survival of fish.

Working: A dissolved oxygen sensor could be used to monitor the oxygen concentration in the tank. As soon as the oxygen level has reached a critical level, the ESP32 microcontroller switches on the oxygen pump to reaerate the water. When optimal oxygen levels have been reached, the pump automatically switches off to conserve energy.

Blynk IoT Dashboard: The dashboard will let the user remotely control and monitor the levels of its parameters – feeding schedules, temperature, and pH levels as well. The user will get real-time notifications in case there are anomalies, ensuring prompt action.

VI. RESULTS

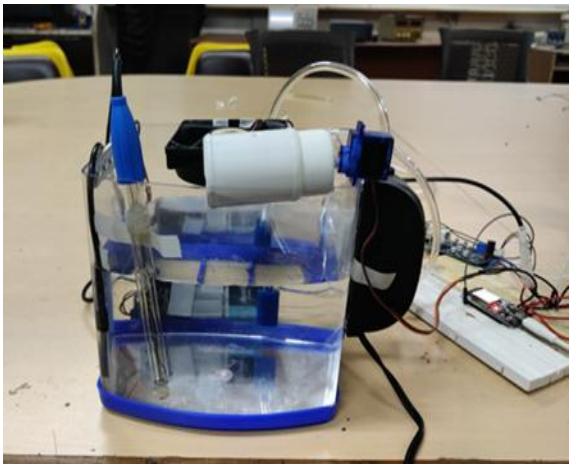

Fig. 5. Prototype of the system

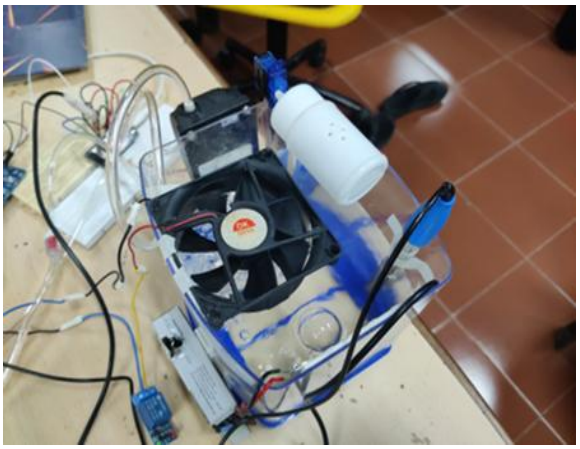

Fig. 6. Prototype of the system

Fig. 7. Blynk Dashboard

Fig. 8. Mobile Interface

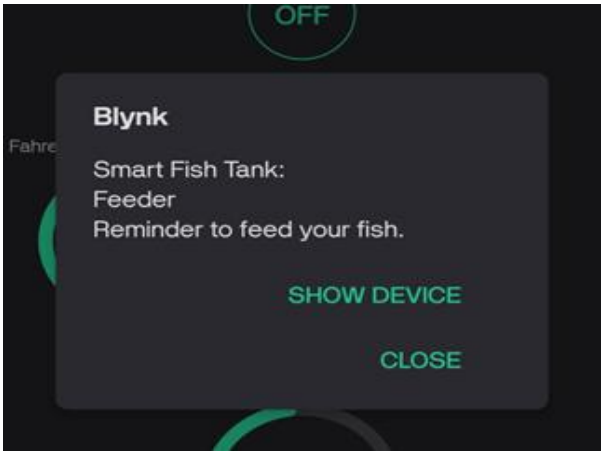

Fig. 9. Pop up Notification

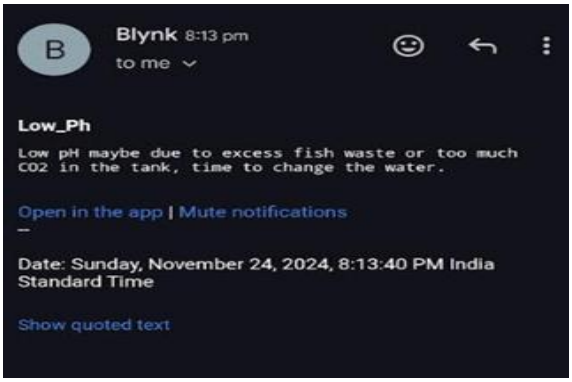

Fig. 10. Email Notification

VII. CONCLUSION

The "AquaSmart" fully delivers an automated and integrated fish tank management system designed to enhance user experience, optimize fish care, and ensure a sustainable aquatic environment. By incorporating key features such as real-time water monitoring, automatic feeding, oxygen pump integration, and a user-friendly interface, this system not only simplifies the tasks associated with fish tank maintenance but also improves the well-being of aquatic life. The project emphasizes reliability and durability by using corrosion-resistant materials and robust construction techniques, ensuring long-term functionality with minimal upkeep. Furthermore, the cost-effective solutions and use of open-source platforms make this system accessible for small-scale aquaculture, providing an affordable and efficient alternative to traditional fish tank setup. Through the continuous monitoring of critical water parameters like pH, temperature, and oxygen levels, along with timely notifications, users are empowered to maintain optimal living conditions for fish, leading to healthier ecosystems. The automated feeding and oxygenation systems ensure precision and consistency, reducing the chances of human error. Overall, this innovative approach to fish tank management not only advances the field of aquaculture but also presents valuable opportunities for future applications in agriculture and water management. The integration of IoT technology into everyday practices showcases the potential of smart systems to transform traditional methods, making them more efficient, reliable, and sustainable.

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