IoT-Based Smart Fish Aquarium System for Real-Time Water Quality Monitoring and Automated Control

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ABSTRACT

This paper presents an automated Internet of Things (IoT)-based system designed to monitor and control environmental conditions within a fish aquarium. Maintaining optimal water quality parameters such as temperature, pH level, turbidity, and water level is crucial for ensuring fish health and survival. Traditional aquarium management methods rely on manual observation and periodic testing, which are often inaccurate, inefficient, and prone to human error. To overcome these limitations, the proposed Smart Fish Aquarium integrates multiple sensors with a NodeMCU (ESP8266) microcontroller connected to a cloud platform. The system continuously collects real-time data from sensors, processes it using embedded automation logic, and triggers control actions—such as operating a heater, aerator, or water pump—through relay modules. Additionally, users can remotely monitor aquarium conditions and receive alerts via a mobile or web dashboard using Wi-Fi or GSM communication. Operating on a client–server model, the proposed IoT-based Smart Fish Aquarium promotes sustainable aquatic management, reduces manual effort, and ensures a stable and healthy environment for aquatic life.

Keywords: IoT, NodeMCU (ESP8266), Sensors, pH, Temperature, Turbidity, Water Level, Ubidots, Blynk, Wi-Fi, Automation.

I. INTRODUCTION

In recent years, the maintenance of aquatic life in both domestic and commercial aquariums has become increasingly challenging due to the growing demand for ornamental fish and aquaculture-based industries. The survival and well-being of fish depend heavily on maintaining stable water quality parameters such as temperature, pH level, dissolved oxygen, and turbidity. Even slight fluctuations in these factors can lead to stress, disease, or mortality among aquatic organisms. Traditional aquarium management practices rely on manual observation and periodic testing, which are often time-consuming, inaccurate, and inefficient. As a result, maintaining an optimal aquatic environment becomes a complex task, especially when continuous supervision is not possible.The lack of automated monitoring and control mechanisms often leads to delayed corrective actions when water parameters deviate from safe limits. For instance, a sudden drop in temperature or oxygen level can harm sensitive fish species within minutes. Similarly, excessive turbidity or pH imbalance can deteriorate water quality, promote bacterial growth, and disrupt the biological equilibrium of the ecosystem. These challenges not only affect the health and longevity of fish but also lead to economic losses in aquaculture industries and hobbyist setups.With the advent of the Internet of Things (IoT), it has become feasible to integrate sensing, computation, and communication technologies into a single intelligent system capable of autonomous operation. IoT-enabled devices can continuously monitor environmental parameters, process real-time data, and trigger automated responses without human intervention. Applying this concept to aquarium management can revolutionize the way aquatic systems are maintained. The proposed Smart Fish Aquarium leverages IoT technology to provide an intelligent, automated, and user-friendly solution for ensuring a healthy aquatic environment.The system employs a combination of sensors—including temperature, pH, turbidity, and water level sensors—interfaced with a NodeMCU (ESP8266) microcontroller. The collected data are transmitted to cloud platforms such as Ubidots or Blynk via Wi-Fi or GSM communication for real-time visualization and remote access. When abnormal conditions are detected, the system automatically activates the corresponding actuators, such as the heater, aerator, or water pump, to restore the desired parameters. Additionally, users can receive instnt alerts and monitor their aquariums remotely through a mobile or web application.

II. LITERATURE SURVEY

IoT-based smart aquarium systems have been investigated by numerous researchers to enhance aquatic environment management and ensure the well-being of fish. Early systems primarily utilized microcontrollers such as Arduino or NodeMCU to collect water quality data—including temperature, pH, and turbidity—and display it locally. While these prototypes demonstrated the feasibility of automated monitoring, they often lacked real-time remote access and efficient control mechanisms, limiting their practical usability in dynamic aquatic environments.Subsequent advancements introduced Wi-Fi-enabled modules that transmitted sensor data to cloud platforms like ThingSpeak, Ubidots, or Blynk, allowing users to monitor water parameters remotely through mobile or web dashboards. This real-time communication capability significantly improved the management of aquariums by enabling timely corrective actions and reducing manual supervision. However, many of these systems were limited to data monitoring and did not incorporate automated actuation to maintain ideal conditions when deviations occurred.Enhanced systems integrated automation logic with the monitoring framework by employing relay modules to control devices such as heaters, aerators, and water pumps. This integration ensured that corrective actions were triggered automatically whenever sensor readings exceeded predefined thresholds, maintaining the stability of the aquatic ecosystem. Furthermore, data filtering techniques—such as median and exponential moving average (EMA) filters—were introduced to minimize sensor noise and improve measurement accuracy.More recent studies explored the use of GSM and LoRa communication modules to enable long-range connectivity in large-scale aquaculture farms. Some systems also experimented with machine learning algorithms, such as Decision Trees and Regression models, to predict variations in water quality or fish behavior. Although these approaches showed promising results, they required substantial computational resources and large datasets, making them less suitable for low-power embedded systems.

III. PROPOSED SYSTEM

TheSmart Fish Aquarium is an automated aquarium management system built on the NodeMCU (ESP8266) microcontroller platform, integrated with multiple water quality sensors and IoT connectivity. The system comprises two main components: mechanical elements and electronic components.

The mechanical section includes the aquarium tank, aeration system, heater, and water pump, while the electronic components consist of sensors (temperature, pH, turbidity, and water level), relay module, LCD display, optional GSM module, and Wi-Fi-based cloud connectivity using platforms such as Ubidots or Blynk.

When the system is powered on, the sensors continuously monitor water quality parameters in real time. The NodeMCU collects data from all sensors, processes it, and compares the readings against predefined threshold values. If any parameter deviates from the desired range, the corresponding actuator—such as the heater, aerator, or water pump—is automatically activated through the relay module to restore optimal conditions.

Simultaneously, the system uploads real-time data to the cloud, enabling users to monitor the aquarium remotely through a mobile or web dashboard. If extreme fluctuations are detected, instant notifications or alerts are sent to the user's smartphone.

Advantages of the Proposed System

Continuous real-time monitoring of key water parameters
Automated control ensures a stable aquatic environment Remote
access through Wi-Fi or GSM-based connectivity Low-cost,
compact, and energy-efficient design
Scalable and modular architecture for expansion to multiple tanks Cloud data
logging and analytics for long-term performance tracking Simple operation and
minimal maintenance

System Components

Aquarium Tank

A standard glass or acrylic fish tank of capacity 30–100 liters houses all aquatic components. The heater, aerator, and sensors are installed inside the tank, while the controller and power circuitry are mounted externally in a waterproof enclosure.

Sensors

Temperature Sensor (DS18B20/DHT11):

Measures real-time water temperature and sends data to the NodeMCU for automatic heater control. Operating Voltage: 3.0–5.5 VDC
Temperature Range: –10°C to +85°C

pH Sensor (SEN0161):

Monitors acidity or alkalinity of the water to ensure a healthy aquatic environment.
Operating Voltage: 5 VDC pH
Range: 0–14
Accuracy: ±0.1 pH

Turbidity Sensor:

Detects water clarity and contamination levels by measuring light scattering through the water. Operating Voltage: 5 VDC
Detection Range: 0–1000 NTU

Water Level Sensor (Float or Ultrasonic):
Detects water level fluctuations to automatically refill or drain water when required. Operating
Voltage: 3.3–5 VDC
Range: 2–400 cm (for ultrasonic variant)

Microcontroller: NodeMCU (ESP8266)
Acts as the central processing unit of the system, collecting sensor data, executing automation logic, and transmitting information to the cloud.
Operating Voltage: 3.3 VDC
Wi-Fi Standard: IEEE 802.11 b/g/n Communication
Protocols: UART, I²C, SPI

Relay Module
Enables the NodeMCU to control high-power devices like the heater, aerator, and water pump automatically. Operating
Voltage: 5 VDC
Relay Type: Single-channel or multi-channel Load
Capacity: 10 A / 250 VAC

LCD Display
Displays real-time water parameter readings (temperature, pH, turbidity, and water level) and system status. Operating
Voltage: 5 VDC
Current Consumption: 1–2 mA (without backlight)

Wi-Fi / GSM Module
Wi-Fi (Built-in ESP8266): Provides wireless connectivity for cloud communication via Ubidots or Blynk.
GSM Module (SIM800L, Optional): Used for remote monitoring and SMS alerts in areas without Wi-Fi coverage. Operating
Voltage: 3.4–4.4 VDC
Frequency Bands: 850/900/1800/1900 MHz

Power Supply
Supplies power to the NodeMCU, sensors, and actuators. Input
Voltage: 220–240 VAC
Output: 5V/12V regulated DC (depending on components) Includes
overcurrent and surge protection for safety.

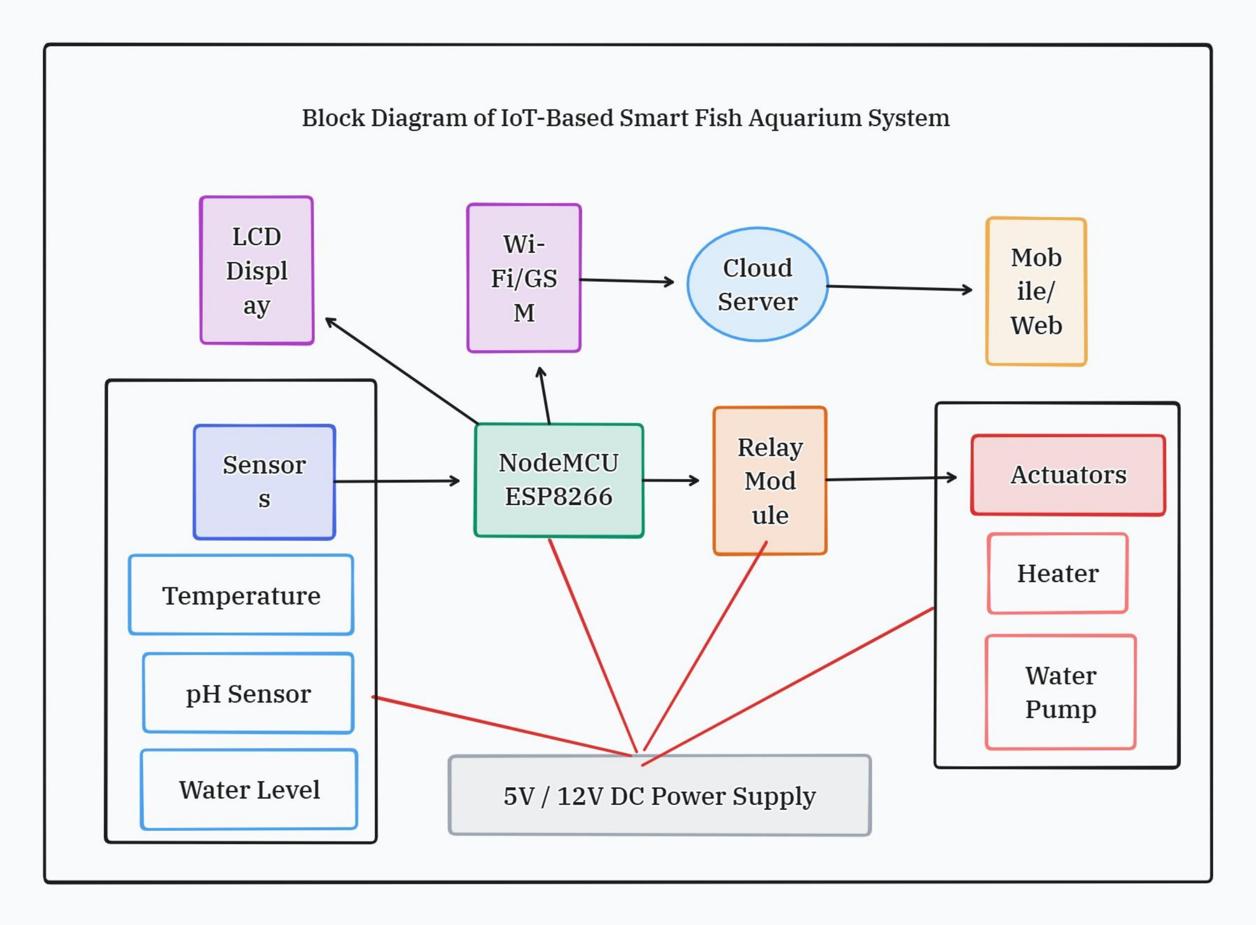
Aerator
Maintains dissolved oxygen levels by continuously supplying air bubbles to the tank. Voltage: 12
VDC or 220 VAC
Power Consumption: 2–5 W

Heater
Maintains water temperature within the ideal range for fish health. Controlled automatically via relay module. Voltage: 220 VAC
Power Rating: 25–100 W (depending on tank size)

Water Pump
Used to circulate and filter water to prevent stagnation and maintain cleanliness. Operating Voltage:
12 VDC / 220 VAC
Flow Rate: 300–1000 L/h

Cloud Platform (Ubidots/Blynk)
Used for data visualization, cloud storage, and mobile access.
Features dashboards for parameter monitoring, manual control, and push notifications when limits are exceeded.

BLOCK DIAGRAM



IV. METHODOLOGY

- **Water Parameter Monitoring**: Sensors placed in the aquarium continuously measure vital parameters such as temperature, pH, turbidity, and water level. These readings are sent to the NodeMCU (ESP8266) microcontroller for real-time analysis.
- **Data Analysis and Threshold Comparison**: The NodeMCU processes the sensor data and compares each reading with predefined safe ranges for fish health. If any parameter exceeds its threshold, the system automatically initiates corrective actions.
- **Automatic Control Operation**: The relay module controls devices based on the analyzed data:
    - The heater activates when the water temperature drops below the ideal range.
    - The aerator turns on when oxygen or water clarity levels decrease.
    - The water pump starts when the water level falls below the minimum set limit.
- **Cloud Communication and Data Visualization:** The system uses Wi-Fi connectivity to send real-time data to IoT platforms such as Ubidots or Blynk. Users can monitor live readings, view historical data, and manually control aquarium devices through a mobile or web dashboard.
- **Alert Notification:** If any parameter remains abnormal for a prolonged period, the system sends an instant alert notification to the user's smartphone, ensuring quick corrective action.
- **System Coordination:** The NodeMCU microcontroller coordinates all components — sensors, relay module, actuators (heater, aerator, pump), LCD display, and Wi-Fi communication — ensuring synchronized and energy-efficient operation of the Smart Fish Aquarium.

V. CONCLUSION

Maintaining ideal water conditions in aquariums is crucial for the health and survival of aquatic life. This paper presents a practical and efficient solution by integrating IoT technology with automated monitoring and control mechanisms for aquariums. The proposed Smart Fish Aquarium System continuously observes key parameters such as temperature, pH, turbidity, and water level, while automatically operating the heater, aerator, and water pump to maintain optimal conditions. Through real-time cloud connectivity, users can remotely monitor aquarium status and receive alerts for any abnormalities. The system reduces manual effort, ensures a stable and healthy aquatic environment, and demonstrates an effective, low-cost, and user- friendly approach to modern aquarium management.

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