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AI Powered IoT Driven Automated Aquarium Ecosystem Administrator

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ABSTRACT

Aquarium maintenance [1][3] demands continuous monitoring and timely intervention to sustain a healthy aquatic environment. This paper presents the development of a smart, IoT-enabled automated aquarium system designed to simplify aquarium management through real-time monitoring and automation. The system utilizes an Arduino Uno integrated with TDS and temperature sensors [4][13] to monitor essential water quality parameters, such as dissolved solids and temperature. A NodeMCU ESP8266 microcontroller with built-in Wi-Fi enables seamless wireless communication, allowing users to monitor data and control operations remotely via a web or mobile interface.

The system also features an automated feeder that ensures consistent feeding based on a preset schedule or remote user commands. An alert mechanism notifies users when water quality deviates from optimal conditions, enhancing responsiveness. Designed to be cost-effective, scalable, and user-friendly, the system reduces manual intervention while promoting the sustainability of aquatic life. Experimental results confirm the reliability and efficiency of the system, making it suitable for both home aquarium enthusiasts and small-scale aquaculture. Its modular architecture allows for future integration with additional sensors and devices, offering flexibility for upgrades. This automated solution provides peace of mind to users by ensuring that the aquarium environment is continuously monitored[2][14] and maintained with minimal human involvement.

INTRODUCTION

In the contemporary landscape of smart technology and environmental sustainability, the **AI Enabled IoT Driven Automated Aquarium Ecosystem Administrator** emerges as a ground breaking innovation that redefines the way aquatic ecosystems are maintained and monitored. Designed to relieve aquarium enthusiasts of the time-consuming and technically demanding responsibilities of aquarium care, this project presents a seamless integration of Artificial Intelligence (AI) and the Internet of Things (IoT)[4][9] — two of the most transformative technologies of our time.

Traditional aquarium systems often require manual oversight for tasks such as water replacement, temperature regulation, and feeding — all of which are vital for the survival and well-being of aquatic life. Failure to maintain parameters such as optimal temperature (typically between 22°C and 28°C)[15][7], water quality based on PPM (parts per million), and timely feeding can lead to significant stress or even mortality among fish and aquatic plants.

This becomes particularly challenging for individuals with busy lifestyles or during periods of travel, where consistent care may not be possible. This invention addresses these challenges through a fully automated system that not only performs routine tasks but dynamically responds to real-time changes in the aquarium environment.

A sophisticated network of sensors continuously monitors key parameters such as temperature, water quality, light levels, and feeding schedules[16][20]. The data collected is then processed by AI algorithms that can detect anomalies, predict future needs, and make intelligent decisions to maintain optimal living conditions — all without human intervention.

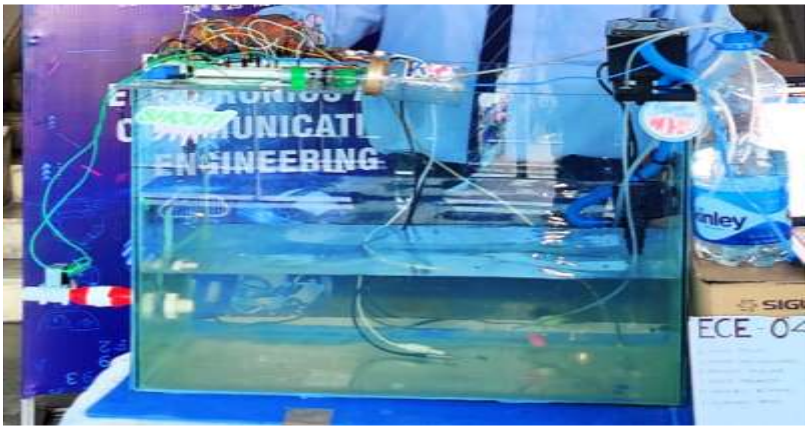

Fig.1- Front view of the working prototype

What sets this system apart is its **holistic and adaptive** approach. While some smart aquarium products exist on the market, they are often limited to individual functionalities — such as automatic feeders or basic temperature sensors — without any centralized, intelligent coordination. This invention, however, integrates all critical components into a unified platform, providing a **comprehensive and intelligent solution** for aquarium management. It not only automates, but also **optimizes**, ensuring both convenience and ecological balance. In a world increasingly driven by automation and sustainability, the AI Enabled IoT Driven Automated Aquarium Ecosystem Administrator represents more than just a smart device — it stands as a **pioneering model** of how advanced technology can harmonize with nature. It transforms aquarium care from a reactive chore into a proactive, intelligent, and sustainable practice, setting a new standard for innovation in smart home ecosystems.

Technology and Methodology

This project is aimed at the design and development of a Smart Automated Water Quality Management and Fish Feeding System[12][8], using the latest embedded technology to monitor water parameters, maintain healthy water conditions, and automate fish feeding. The major components involved are Arduino UNO, NodeMCU ESP8266, Ultrasonic Sensor, Solenoid Valve, Relay Circuit, Water Pump Motor, Heater, Servo Motor, Breadboard, Transistor.

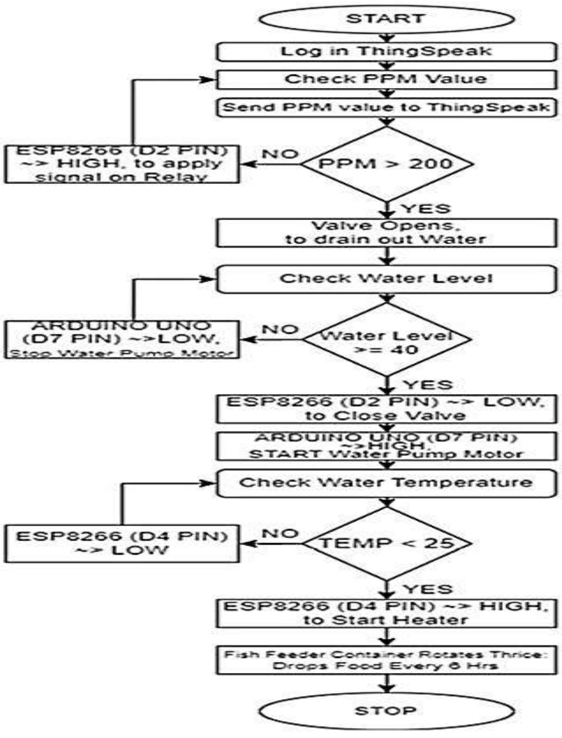

Fig. 2-The system is based on a flowchart-controlled sequence, ensuring an automated and efficient operation, which is explained step-by-step below.

1. Data Logging to ThingSpeak:
The NodeMCU ESP8266 connects to Wi-Fi and logs sensor data to the IoT platform ThingSpeak for remote monitoring[18][6]. Sensor readings such as TDS are uploaded using the formula:
$PPM_{sent} = PPM_{measure}d$,
where PPM is calculated by:
PPM = (V_out × 1000) / 5 × K,
with V_out as the sensor's output voltage and K as a calibration constant.

2. PPM Monitoring and Drainage Control:
If the water's PPM exceeds 200, indicating poor quality, the NodeMCU sets pin D2 HIGH, activating a relay that opens a solenoid valve to drain the water.
Logic: If PPM > 200 → D2 = HIGH; Else → D2 = LOW

3. Solenoid Valve and Relay:
The solenoid valve, triggered via a relay and an NPN transistor, opens to drain water. The relay is energized by a 3.3V signal from D2.

4. Water Level Monitoring:
An ultrasonic sensor (HC-SR04) measures distance to the water surface:

Distance = Time × 0.0343 cm
Water Level = Tank Height – Distance
If the water level drops below 40 units, the solenoid closes and the refill pump starts.

5. Water Refilling:
The Arduino UNO controls the water pump via its D7 pin.

D7 HIGH → Motor ON; D7 LOW → Motor OFF
The base current for the switching transistor is:

I_b = (V_in – V_be) / R_b

6. Temperature Monitoring:
A DS18B20 sensor checks water temperature[19][11].

Temperature = Sensor Reading × Calibration Constant
If temperature < 25°C, ESP8266 D4 = HIGH, turning the heater ON via relay.

7. Heater Operation:
D4 HIGH → Heater ON; D4 LOW → Heater OFF
This ensures a suitable thermal environment for aquatic life.

8. Automated Feeding:
Every 6 hours, a servo motor rotates a fish feeder 3 times.

θ = Pulse Width × Servo Constant
PWM signals from Arduino control the servo's motion.
9. Circuit Integration:
All components are interconnected via a breadboard using jumper wires, resistors (for current limiting), diodes (to block back EMF), and transistors (as switches for motors and relays).

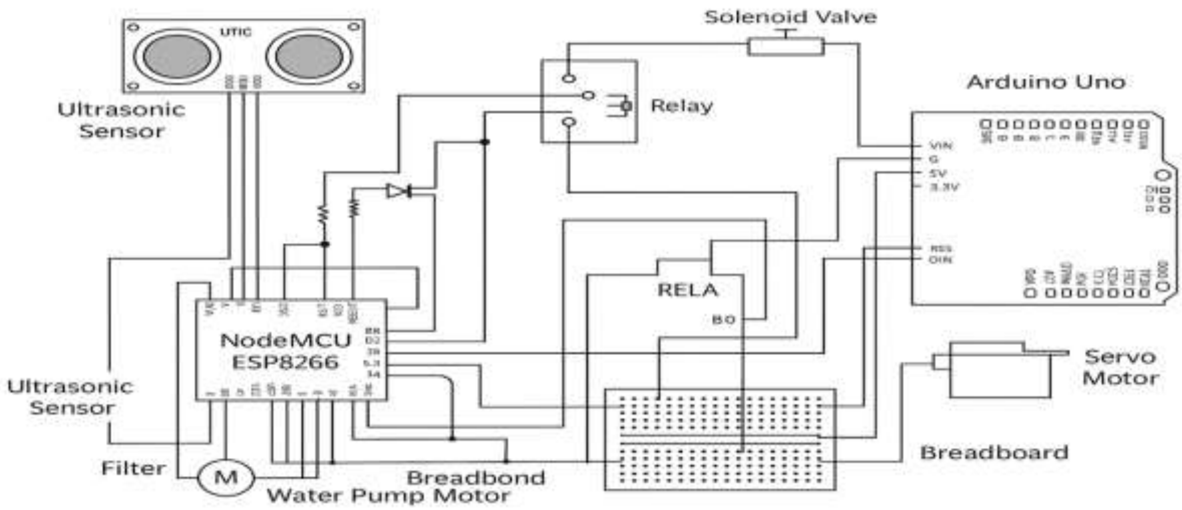

Fig. 3- CIRCUITRY where all activities are synchronized and monitored through the ThingSpeak cloud platform.

10. System Safety & Reliability: The use of threshold-based logic ensures that critical operations like heating, draining, and feeding only occur when necessary. This logic helps prevent over draining, overheating, or overfeeding, thus maintaining a balanced and safe aquatic ecosystem. All sensor readings[5][10] (PPM, temperature, water level) and device statuses (heater, valve, pump, feeder) are periodically sent to the ThingSpeak platform. Users can access and monitor this data remotely through a web interface or mobile app, allowing real-time awareness and system control.

RESULT AND DISCUSSIONS

During the development and exhibition of our automated aquarium project, extensive testing confirmed the system's ability to function autonomously and reliably, without human intervention. Our aim was to develop a fully automated solution capable of maintaining optimal aquatic conditions consistently. Through multiple iterations and enhancements, we achieved a final prototype that met all operational expectations. In internal tests, the system accurately regulated key parameters such as temperature, TDS (ppm), water clarity, and feeding using a network of sensors and responsive actuators, including heaters, pumps, and filtration systems. These components were centrally managed by a control unit programmed for real-time monitoring and adjustment.

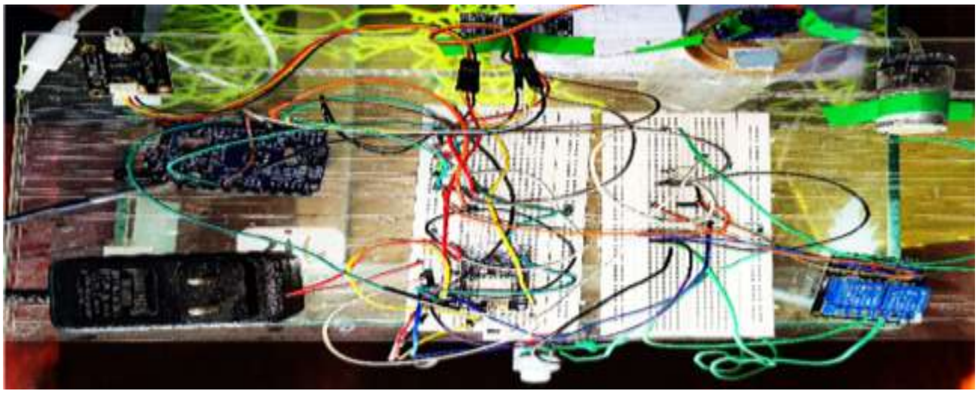

Fig. 4-Top view of the circuit

A major technological integration was **ThingSpeak**, an open-source IoT platform used for live data logging and remote monitoring. Sensor data was uploaded at intervals of 30 seconds to 1 minute, with remarkable consistency and minimal data loss. The platform offered real-time visualization of the system's performance, validating the system’s stability and effectiveness. Our public demonstration at **JISTECH 2023** was a highlight, attracting attention from students, faculty, and industry experts. gained strong encouragement, particularly regarding its potential for commercialization. The system’s **fail-safe mechanisms**—including AI-based fallback settings during sensor or network failures—further reinforced its reliability and appeal.

Fig.5-ThingSpeak dashboard

The successful live demonstration, combined with ThingSpeak's consistent data logging and the system's autonomous functionality, underscored its robustness and readiness for real-world applications. Beyond technical success, this project marked a pivotal academic and entrepreneurial milestone, proving that thoughtfully implemented innovation can address real-world problems and deliver both ecological and commercial value. We remain committed to refining and scaling this system for broader use in both home and industrial aquaculture.

CONCLUSION

The AI Enabled IoT Driven Automated Aquarium Ecosystem Administrator marks a transformative leap in home aquarium management, merging cutting-edge AI and IoT technologies to deliver intelligent, sustainable care for aquatic life. By continuously monitoring vital parameters like temperature and water quality using advanced sensors, the system ensures optimal conditions for aquatic health. Its standout feature—autonomous water removal and replenishment—eliminates the need for human intervention, offering unmatched convenience for users with busy lifestyles. The integration of TDS and temperature sensors, along with Arduino and Wi-Fi modules, enables real-time data analysis and system control. This data is uploaded to a dedicated website, keeping users constantly informed. Beyond just automation, the system manages water flow, regulates feeding, and maintains ideal environmental conditions, all while promoting ecological responsibility. This innovation not only reduces labour and costs but also fosters a sustainable and educational approach to aquarium care. By addressing the major challenges faced by enthusiasts, it redefines the standards of aquatic ecosystem management. Ultimately, this project stands as a beacon of progress, proving that technology and ecology can harmoniously coexist to create a healthier, more sustainable future for all.

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