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Fish Tank: An IoT-Based Mini Aquarium Control System

Purushottam S. Chavan, Mitali A. Nandanwar, Vedika J. Pardeshi,
Sanika Y. Kute, Anushka A. Darade
Department of Computer Technology
K. K. Wagh Polytechnic Nashik, Maharashtra, India

Abstract: *The manual management of aquarium systems is a meticulous process involving hands-on monitoring of various critical parameters such as water quality, feeding, lighting, and maintenance. However, this approach comes with challenges, including significant time consumption, the potential for human errors, and a lack of remote monitoring capabilities. To overcome these challenges, the development of automated smart aquarium systems has emerged as a transformative solution. These systems aim to simplify maintenance, enhance the well-being of aquatic life, provide remote accessibility, and contribute valuable data for research and education in the field. In the context of this evolutionary shift, this paper proposes a comprehensive Fish Tank system built upon the innovative IoT solution, IoT talk. This system utilizes sensors to drive actuators in real-time, enabling intelligent control of various water conditions within the aquarium. A notable feature of this proposed system is the implementation of a precise fish-feeding mechanism, enhancing the overall care provided to aquatic life. The paper goes further to present an analytic model, simulation, and measurement experiments that delve into the effects of IoT message delays and loss on water condition control, contributing valuable insights to the efficiency of the proposed system. Moreover, the proposed Fish Tank system incorporates advanced monitoring tools seamlessly connected to a robust database. This integration allows for efficient data storage and retrieval, enhancing the overall performance and reliability of the system. By extending this connectivity to a mobile application, the solution not only reduces human effort and errors in aquarium management but also provides users with convenient remote access. This transformative approach ensures continuous monitoring and control of the aquarium environment, ultimately contributing to the sustained health and well-being of aquatic life.*

Keywords: Internet of Things (IoT), Water Monitoring, Smart Aquarium, Automated Fish Feeders, Sensors, Actuators

I. INTRODUCTION

In today's fast-paced world, stress relief and a connection with nature are increasingly essential. Scientific studies highlight the therapeutic benefits of watching fish, reducing stress and anxiety levels and promoting relaxation. This calming experience is invaluable in our hectic lives, with fish serving as companions that significantly enhance mental well-being. The positive impact extends to education, especially in institutions for children, where observing fish becomes a powerful tool for imparting knowledge about aquatic ecosystems and environmental conservation. The demand for intensive care of fish, coupled with the challenges humans face in meeting those needs, has brought the Aquarium Control System to the forefront of innovation. This transformative approach redefines the way we care for fish, addressing the intricacies of maintaining a thriving aquatic environment. The integration of Node MCU as the microcontroller seamlessly connected with the Wi-Fi module allows not only remote monitoring but also the automation of essential tasks, ensuring a harmonious habitat for aquatic life. The importance of aquarium systems in homes and various public spaces cannot be understated. However, creating an environment that allows aquatic wonders to thrive is a complex task. The Aquarium Control System revolutionizes the way we care for fish, making it easier to monitor and maintain their well-being. By reducing the death rate of fishes through smart and automated aquarium systems, it emphasizes the necessity of frequent monitoring and cleaning.

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Traditionally, maintaining fish health involved manual monitoring of parameters like water temperature, LED light conditions, and temperature sensors. The Aquarium Control System, powered by IoT technology, elevates this process, offering automation and remote control through a smartphone. This intelligent and adaptable system simplifies upkeep, guaranteeing optimal conditions for fish well-being.

The overarching project focuses on developing an IoT-based mini aquarium control system, meticulously designed for small-scale aquariums. The emphasis on education is not overlooked, as the project seeks to enhance our understanding of aquatic environments while promoting conservation practices. Recognizing the challenges in meeting the needs of aquarium inhabitants, the Aquarium Control System stands as an emblem of innovation. The fusion of technology and nature is exemplified by the integration of the Node MCU microcontroller with the Wi-Fi module. This not only ensures remote monitoring of crucial parameters but also automates essential tasks, creating a harmonious and healthy habitat for aquatic life. The project introduces the Fish Tank system, leveraging IoT talk, an IoT-based solution. This system utilizes aquarium sensors to drive actuators in real time, with examples of threshold conditions and an intelligent fish-feeding mechanism. The cloud-based platform integration ensures real-time insights and automation capabilities, pushing the boundaries of what miniaturized aquatic ecosystems can achieve. At the core of Fish Tank's revolutionary approach is its utilization of IoT, providing advanced monitoring and control systems for mini aquariums. Key to Fish Tank's success is the integration of sophisticated sensors tirelessly working to monitor crucial parameters in real time. From water temperature and feeding patterns to water quality, these sensors play a pivotal role in ensuring the ongoing health and vibrancy of the aquatic life housed within the mini aquarium.

In this introduction sets the stage for a comprehensive exploration of the innovative Fish Tank system. The commitment to reshaping the landscape of miniaturized aquatic ecosystems, and promoting technology, education, and conservation, is evident throughout. The project aspires to lead the way in advancing the care and management of mini aquariums, transcending the traditional boundaries of aquarium maintenance and ushering in an era where technology enhances our connection with the natural world. The profound impact of these miniature aquatic marvels, both in personal spaces and educational institutions, heralds a future where the fusion of technology and nature elevates our understanding and appreciation of the aquatic world.

II. LITERATURE SURVEY

Through extensive research, significant advancements have been made in the development of IoT-based systems for monitoring and controlling fish tanks. However, several challenges persist, including scalability, adaptability to diverse environments, and complexity in algorithm implementation. While these studies offer valuable insights into different approaches, there remains a need for comprehensive solutions addressing the intricacies of maintaining optimal conditions for aquatic life in various settings.

- This study focuses on the development of an IoT-based mini aquarium system that utilizes IoT technology for real-time monitoring and control of water conditions. The system employs sensors to measure various parameters such as water temperature, pH level, and turbidity, providing crucial data for maintaining optimal conditions for aquatic life. Actuators are driven based on sensor data, enabling automated adjustments to water conditions as needed. The system offers the potential for intelligent control of various water conditions, contributing to the well-being of aquatic life in mini aquariums.
- It introduces an IoT-based fish tank monitoring system comprising multiple subsystems for comprehensive monitoring and management. The subsystems include water quality monitoring, video surveillance, feeding, and cloud data storage, providing a holistic approach to fish tank management. Successful data transmission and video surveillance are demonstrated, highlighting the system's capability to monitor and record key parameters in real time. While the system shows promising results, optimization for consistent performance across different upload speeds is identified as an area for improvement.
- The focus of this study is the development of a smart aquarium monitoring system controlled via a smartphone application. Arduino MEGA and NodeMCU controllers are utilized to enable real-time monitoring and control of aquarium conditions. The system employs sensors to detect parameters such as water temperature and pH level, displaying the data through a smartphone application. While the system offers convenience and

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accessibility for aquarium owners, further validation of its effectiveness in maintaining optimal water conditions is recommended.

- Lastly, it proposes a robust IoT-based aquarium control system utilizing the decision tree regression algorithm for real-time monitoring and control. The system aims to overcome limitations in remote aquarium control by providing accurate and real-time monitoring of crucial parameters. Tests are conducted to evaluate system performance, including measurement of sensor data transmission delay and actuator response time. The system's robustness is assessed based on its ability to reach critical points and provide timely alerts to users, ensuring the well-being of aquatic life in the aquarium.

In addition to the above, the proposed Fish Tank system utilizes IoT technology to enable real-time monitoring and control of aquarium conditions. It incorporates sophisticated sensors to monitor crucial parameters such as water temperature. These sensors continuously collect data, which is then transmitted to a central hub using the MQTT (Message Queuing Telemetry Transport) protocol, known for its lightweight and efficient communication capabilities. By providing alert notifications for feeding schedules, the Fish Tank system empowers users to proactively manage their aquariums and respond swiftly to any issues that may arise. This proactive approach to aquarium maintenance helps maintain optimal conditions for aquatic life, promoting their health and longevity. The Fish Tank system allows users to remotely manage their aquariums through a user-friendly interface accessible via a mobile application or web portal. Through this interface, users can view real-time data on water conditions, adjust settings such as lighting and feeding schedules, and receive alerts in case of any anomalies detected by the system. The utilization of the MQTT protocol ensures seamless communication between the sensors and user interface, facilitating rapid data transmission and efficient decision-making.

III. METHODOLOGY

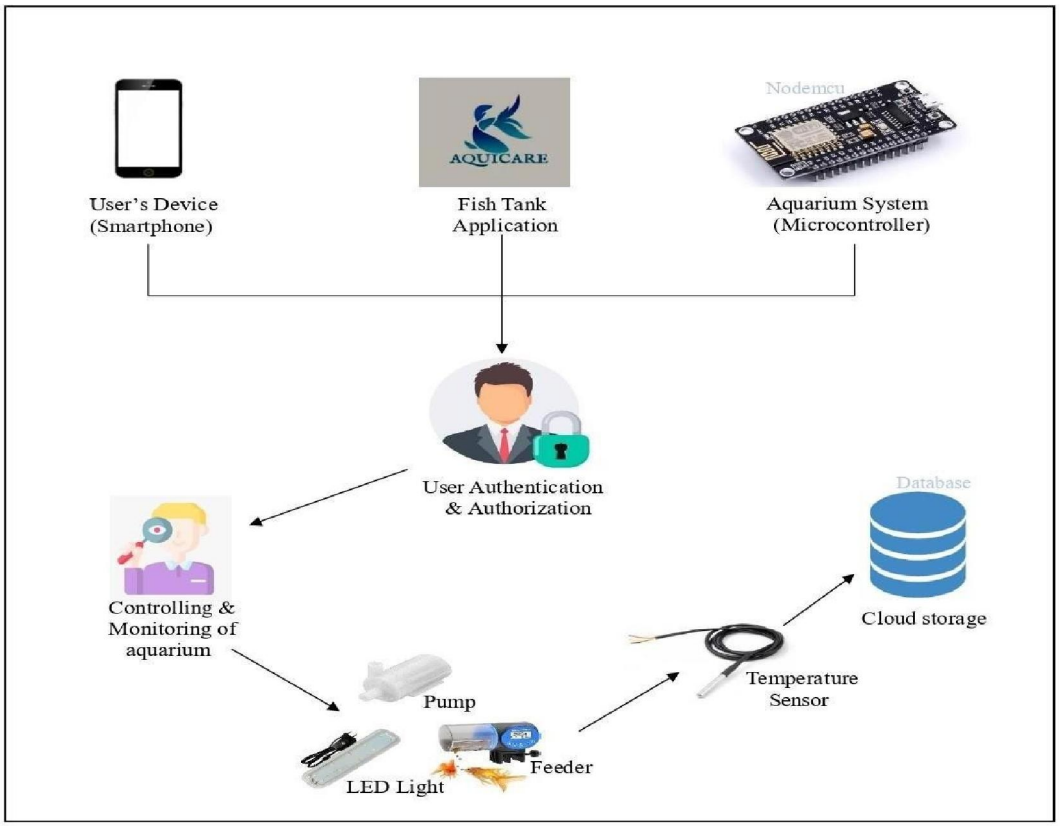

Fig.1 System Architecture Diagram

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User Device (Smartphone, Tablet, etc.):
The user device serves as the primary interface for the smart aquarium application, enabling users to seamlessly interact with and control the aquarium remotely. Whether through a smartphone or tablet, users can register, log in, and access a user-friendly graphical interface. Connectivity is established via the internet, utilizing Wi-Fi or mobile data, facilitating real-time communication with the Smart Aquarium Application Backend.

Aquarium System (Microcontroller):
The aquarium system, governed by a microcontroller, encapsulates crucial components such as the pump controller, light controller, and temperature sensor. These elements collectively regulate the aquarium environment. The pump controller manages water circulation, the light controller controls aquarium illumination, and the temperature sensor measures the water temperature. Wired or wireless connections link the microcontroller to the Smart Aquarium Application Backend, forming the backbone for command reception and data transmission.

User Authentication and Authorization:
Functioning as the security gateway, the User Authentication and Authorization module ensures that only authorized individuals access the smart aquarium application. Robust processes include user registration, where account creation occurs, and subsequent login processes for user authentication. Token-based authorization enhances security, with tokens issued post-login to authenticate and authorize users for subsequent interactions with the Smart Aquarium Application Backend.

Aquarium Control and Monitoring (Smart Aquarium Application Backend):
Serving as the central intelligence hub, the Smart Aquarium Application Backend orchestrates user commands, translates them into control signals, and receives real-time monitoring data from the microcontroller. Processes encompass receiving user inputs, sending control signals for pump and light adjustments, and retrieving monitoring data, notably temperature readings. The backend establishes a vital connection to the microcontroller, facilitating seamless communication for effective control and monitoring of the aquarium system.

Pump, Light, and Feeding Modules (Connected to Microcontroller):
Essential for physical control within the aquarium, individual modules, connected to the microcontroller, manage key components. The pump module regulates water circulation, maintaining optimal conditions for aquatic life. The light module controls aquarium illumination based on user preferences. While not explicitly mentioned, a potential feeding module could automate fish feeding based on user commands. Physical or wireless connections ensure these modules respond accurately to control signals from the microcontroller.

Temperature Sensor (Connected to Microcontroller):
Integral to environmental monitoring, the temperature sensor, interfaced with the microcontroller, accurately gauges the aquarium temperature. This critical data is transmitted back to the Smart Aquarium Application Backend, offering real-time insights into the aquarium's thermal conditions. The wired or wireless connection between the sensor and microcontroller ensures seamless and reliable transmission of temperature data for continuous monitoring and user awareness.

Cloud Storage:
The Cloud Storage module serves as a secure repository for user preferences, aquarium metrics, and other pertinent data. This information, stored in the cloud, facilitates accessibility across devices and permits in-depth data analysis. The Smart Aquarium Application Backend communicates with the Cloud Storage infrastructure over the internet, ensuring data synchronization and enabling users to maintain consistent control and monitoring experiences irrespective of the device used

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Workflow Example:

- The user registers and then logs in on their device using credentials.
- The Smart Aquarium Application Backend validates the login, issues a token, and establishes a secure session.
- The user interacts with the application, sending commands (e.g., turning on the pump) through the front end.
- The Smart Aquarium Application Backend receives the command, translates it into control signals, and sends them to the Microcontroller.
- The Microcontroller interprets the signals, controlling the respective modules (Pump, Light, etc.) accordingly.
- The Temperature Sensor measures the aquarium temperature, and the data is sent back to the Smart Aquarium Application Backend.
- The Smart Aquarium Application Backend stores data in the Cloud Storage for later analysis or accessibility across different devices.

IV. RESULTS

4.1 Hardware Components

Fig.2 MPS module

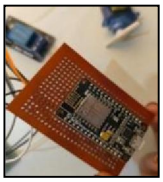

Fig.3 Node MCU

Fig.4 Servo Motor

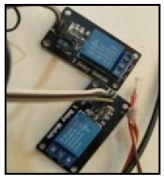

Fig.5 Relay

Fig.6 Temperature Sensor

1. MPS module

The Monolithic Power Systems (MPS) MPM Power Modules, with their integrated DC-DC converters and compact design, serve as efficient power management solutions in an IoT-based fish tank. They provide stable power to IoT components, regulate voltage levels, and offer a small footprint for integration within the limited space of an aquarium. The constant-on-time control scheme ensures fast responses to changing conditions, crucial for maintaining optimal aquatic environments. These modules simplify system design, require minimal external components, and comply with environmental standards, supporting sustainable and eco-friendly IoT applications.

2. Node MCU

The Node MCU (Microcontroller Unit) acts as the central processing unit of the FishTank system. Based on the ESP8266 Wi-Fi module, it processes commands from the Smart Aquarium Application Backend, orchestrates the control of modules such as pumps, lights, and feeding mechanisms, and facilitates communication between various components. The Node MCU is the brain behind the automation and remote-control features, making it a key component in creating an intelligent and interconnected aquarium management system.

3. Servo Motor

The Servo Motor is an actuator employed in the FishTank system for its role in automating the fish-feeding mechanism. This precise and controllable motor allows for the scheduled release of fish food into the aquarium. By automating the feeding process, the servo motor enhances the overall care provided to the aquatic life, ensuring they receive the right amount of food at appropriate intervals without manual intervention.

4. Relay Module

In an IoT-based aquarium system, relay modules serve as switches to control the water pump and lighting. For pump control, the relay module enables automated water circulation, preventing stagnation and ensuring optimal oxygen levels. In lighting control, it manages the aquarium lights, allowing for scheduled on/off cycles and light intensity adjustments to simulate natural day-night cycles

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5. Temperature Sensor

The Temperature Sensor plays a crucial role in monitoring the water temperature within the aquarium. Integrated with the microcontroller, it provides real-time data that allows the system to make necessary adjustments to maintain optimal temperature conditions for the well-being of the aquatic life. The temperature sensor is instrumental in preventing temperature-related stress or harm to the aquarium inhabitants.

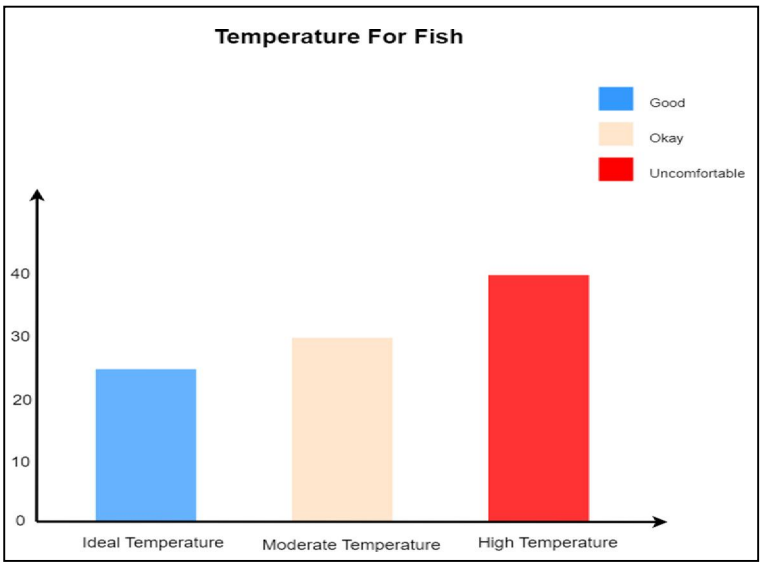

Fig.7 Temperature for comfortness of fishes

In this system, temperature ranges are categorized into three zones to ensure the comfort and health of the in aquatic life. By utilizing the temperature sensor to monitor these temperature zones and implementing appropriate control mechanisms, the aquarium system can effectively maintain a stable and conducive environment for the thriving of its inhabitants, safeguarding them from temperature-related stress or harm.

- **Ideal Temperature (24°C to 26.5°C):** This temperature range provides an ideal environment for most aquarium inhabitants. It is considered optimal for the health, growth, and overall well-being of the aquatic life. Within this range, fishes are typically active, and other aquatic organisms thrive without experiencing stress due to temperature fluctuations.
- **Moderate Temperature (26°C to 30°C):** As the temperature approaches 30°C, it enters the moderate temperature zone. While still within an acceptable range, this temperature level may start to cause slight discomfort for some species. It's crucial to monitor the temperature closely within this range to prevent any adverse effects on the aquatic life.
- **High Temperature (Above 30°C):** Temperatures exceeding 30°C are considered high and can be uncomfortable or even harmful to many aquarium inhabitants. Such elevated temperatures can lead to stress, decreased oxygen levels, and increased susceptibility to diseases. It's essential to take immediate corrective actions, such as adjusting the cooling system or increasing aeration, to bring the temperature back within the safe range and ensure the well-being of the aquatic ecosystem.

Table1: Temperature Ranges

Sr. No.	Temperature Range	Result
1	24°C to 26.5°C	Ideal Temperature (Good for fishes)
2	26°C to 30°C	Moderate Temperature (Acceptable)
3	Above 30°C	High Temperature (Uncomfortable for fishes)

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Fish Tank with All Hardware Connections

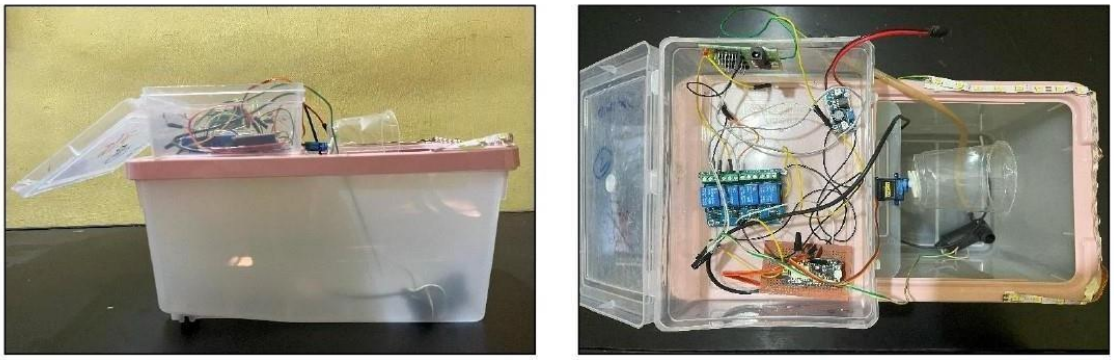

Fig.8 Fish tank with all connections

The hardware configuration depicted in the accompanying photo provides an intricate view of the FishTank system, an innovative IoT-based mini aquarium control system poised to revolutionize aquatic management and education. The setup is meticulously organized, showcasing the seamless integration of electronic components to ensure optimal functionality and performance. Central to the system's operation is the Node MCU microcontroller, positioned at the heart of the setup. This microcontroller serves as the core component responsible for processing data and controlling various actuators within the aquarium. Paired with a Wi-Fi module, the Node MCU enables wireless connectivity, facilitating remote monitoring and control of the aquarium environment. This connectivity grants users convenient access to real-time data and system management capabilities, enhancing overall user experience and ease of operation. The photo captures various sensors strategically positioned within the aquarium, including a temperature sensor dedicated to monitoring water temperature variations. This sensor plays a pivotal role in gathering real-time data essential for maintaining a healthy aquatic ecosystem. By ensuring that the water remains within the optimal temperature range suitable for the fish and other aquatic life, the temperature sensor contributes significantly to the well-being of the inhabitants.

The hardware configuration boasts an array of actuators designed to regulate environmental parameters within the aquarium. A servo motor is tasked with controlling the automatic feeder, dispensing precise portions of food at scheduled intervals. This automated feeding process promotes proper feeding practices and reduces the need for manual intervention, ensuring the nutritional needs of the aquatic inhabitants are met consistently. A water pump integrated into the setup facilitates proper circulation of the water, preventing stagnation and facilitating oxygenation to support aquatic life. Furthermore, LED lights are strategically positioned to provide illumination for plant growth and fish visibility, creating a vibrant and visually appealing aquarium environment conducive to the well-being of its inhabitants. Meticulous attention has been given to the establishment of hardware connections, with appropriate wiring and connectors utilized to ensure reliable communication and functionality. Each component is carefully secured within the aquarium environment, with cable management optimized to minimize clutter and maximize efficiency. This meticulous approach enhances the overall aesthetics and functionality of the system, reflecting the sophistication and innovation inherent in the FishTank system. The detailed hardware configuration exemplifies the FishTank system's ability to empower users to create and maintain thriving aquatic ecosystems. By leveraging advanced technology and thoughtful design, the system not only enhances the well-being of aquarium inhabitants but also fosters educational opportunities for students and enthusiasts interested in aquatic management and conservation

User Interface:

The user interface (UI) of the developed application represents a harmonious integration of intuitive design elements meticulously crafted to elevate user experience and functionality. It embarks on a captivating journey from the moment users encounter the splash screen, which serves as an inviting gateway into the application's world. This initial interaction sets the tone for users' engagement and establishes a sense of anticipation for what lies ahead.

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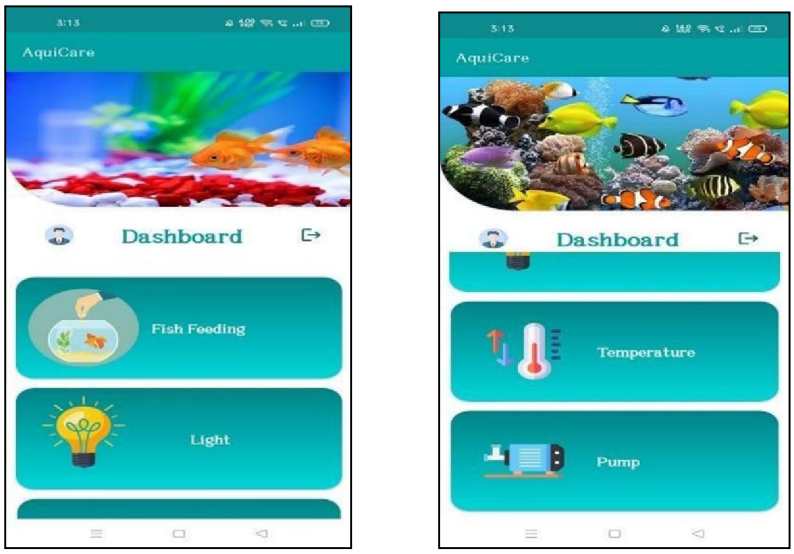

Fig.9 User Interface of the application

Upon progressing past the splash screen, users are welcomed by a user-friendly login interface, designed with simplicity and accessibility in mind. Here, users can seamlessly access their accounts or initiate the registration process for new ones via a streamlined registration flow. This ensures that users can swiftly transition into the application and begin exploring its offerings without unnecessary barriers. Once logged in, users are introduced to a dynamic dashboard, strategically positioned as the central command center for navigation and interaction. The dashboard provides a comprehensive overview of key features and functionalities, offering convenient access to essential controls such as feeding schedules, lighting adjustments, temperature monitoring, and pump management. This centralized hub enhances user efficiency by consolidating vital information and tools within easy reach.

An intuitive user profile icon prominently featured on the dashboard further enhances user convenience by providing direct access to essential account management functionalities. With a simple click, users can access their username and contact information, facilitating seamless identification and communication within the application's ecosystem. Additionally, the inclusion of a logout button ensures that users can securely sign out of their accounts whenever desired, prioritizing data security and user privacy. Each element of the user interface is meticulously designed to prioritize clarity, consistency, and ease of use, thereby empowering users to navigate the application effortlessly. The feeding interface offers granular control over feeding schedules, enabling users to tailor feeding routines to the unique needs of their aquatic inhabitants. Similarly, the lighting interface facilitates precise adjustments to lighting conditions, accommodating the preferences of diverse aquatic life forms. The temperature interface provides real-time monitoring of water temperature, empowering users to maintain optimal environmental conditions critical for the health and well-being of their aquatic ecosystem. Similarly, the pump interface offers intuitive controls for regulating water circulation effectively, ensuring adequate oxygenation and preventing stagnation. Through cohesive visual design, responsive layout, and intuitive interaction patterns, the UI cultivates a seamless and immersive user experience, reinforcing the application's commitment to usability and customer satisfaction

V. CONCLUSION

The IoT-based mini aquarium control system is a sophisticated yet user-friendly solution designed for aquarium enthusiasts. By integrating key features like Fish feeding, pump control, temperature sensing, and LED light management, Notifications this system enhances the overall aquarium management experience. The automated feeding feature ensures that fish and other aquatic life receive their required food consistently, reducing the risk of over or underfeeding without the need for manual intervention. The pump control function maintains optimal water circulation, which is vital for sustaining healthy oxygen levels and promoting a thriving aquatic environment. Real-time temperature sensing allows users to monitor water temperature continuously, which is essential for creating and

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maintaining the ideal living conditions for aquatic organisms. Additionally, the LED light management feature enables users to adjust lighting settings to simulate natural day-night cycles, supporting the biological rhythms of the aquarium inhabitants. The system's remote monitoring and control capabilities empower users to manage their aquariums from anywhere with internet access, offering unmatched flexibility and convenience. This feature allows proactive management by enabling users to monitor aquarium parameters and make necessary adjustments to ensure the well-being of their aquatic ecosystem, even when they're not at home. Furthermore, the inclusion of feeding notifications adds another layer of functionality to the system. Users can schedule specific feeding times, and the system will send reminders to ensure that their aquatic pets receive their meals on time, providing peace of mind even when users are away. In essence, the IoT-based mini aquarium control system seamlessly integrates advanced technology with practical features to offer a comprehensive solution that prioritizes the health and well-being of aquarium inhabitants while providing convenience and assurance to enthusiasts.

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