Smart Aquarium System: Water Change and Temperature Control with HC-SR04 and DS18B20 Sensors Based on IoT

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Abstract: The Internet of Things (IoT) is increasingly used in aquarium maintenance. This study develops a smart aquarium system for automating water changes and temperature control. The system uses the HC-SR04 ultrasonic sensor to monitor water levels, with Pump 1 removing water to a depth of 20 cm and Pump 2 refilling up to 5 cm. Temperature control is managed by the DS18B20 sensor, using relays to activate the heater if the temperature drops below 22°C and the fan if it exceeds 30°C. The system is controlled via an IoT platform connected to a Telegram bot, with data displayed on an LCD screen. Testing results showed that the water level control system performed efficiently, with pumps responding within 5 seconds, maintaining consistent water levels. However, temperature control exhibited a 1-minute delay before activating the heater or fan, ensuring stable temperature regulation. This system successfully maintained water temperature between 22°C and 30°C during the testing period. In the future, the system could be enhanced by adding a photodiode sensor for water clarity, a pH sensor for water quality, and UV light control in the filter chamber to further optimize water conditions, making it a practical solution for long-term aquarium maintenance.

Keywords: IoT, smart aquarium, temperature control, Telegram bot, water change.

Introduction

The application of Internet of Things (IoT) technology is becoming increasingly important in aquarium management, especially for enhancing efficiency and convenience in the maintenance of ornamental predator fish such as channa or arowana. This study is conducted in collaboration with Lucky Garibaldi, the owner of a predator ornamental fish business located on Jalan Bima, Bandung. The smart aquarium system developed in this research aims to address various challenges in the maintenance of predator fish, while improving fish quality and enhancing the efficiency of aquarium care.

Ensuring optimal conditions manually can be labor-intensive and prone to errors, making automated systems highly beneficial. By utilizing IoT, aquarium maintenance can be conducted more efficiently, minimizing human error and ensuring consistency in care.

Ultraviolet (UV) light is commonly used in aquarium filtration systems to sterilize water by killing bacteria, viruses, and algae. UV sterilization helps maintain water clarity and reduces the likelihood of harmful pathogens that can affect the health of fish. In the smart aquarium system, UV light is incorporated into the biological and chemical filtration process within the chamber filter. This ensures that water passing through the filter is free from microbial contaminants, supporting a healthy and clean environment for the fish.

Aquarium maintenance for predator fish such as channa or arowana often faces specific challenges related to water quality and temperature stability, both of which are critical for the health and growth of these species.

The system focuses on two key aspects: automated water replacement and temperature control. Water replacement is managed using an ultrasonic sensor to monitor water levels, with Pump 1 designed to drain water down to a depth of 20 cm, and Pump 2 refilling the tank until the water reaches a 5 cm level. Temperature control is handled by a DS18B20 temperature sensor, which activates a heater when the temperature falls below 22°C and turns on a fan when it rises above 30°C. Both of these functions are critical for maintaining a stable environment, which is essential for the well-being of predator fish.

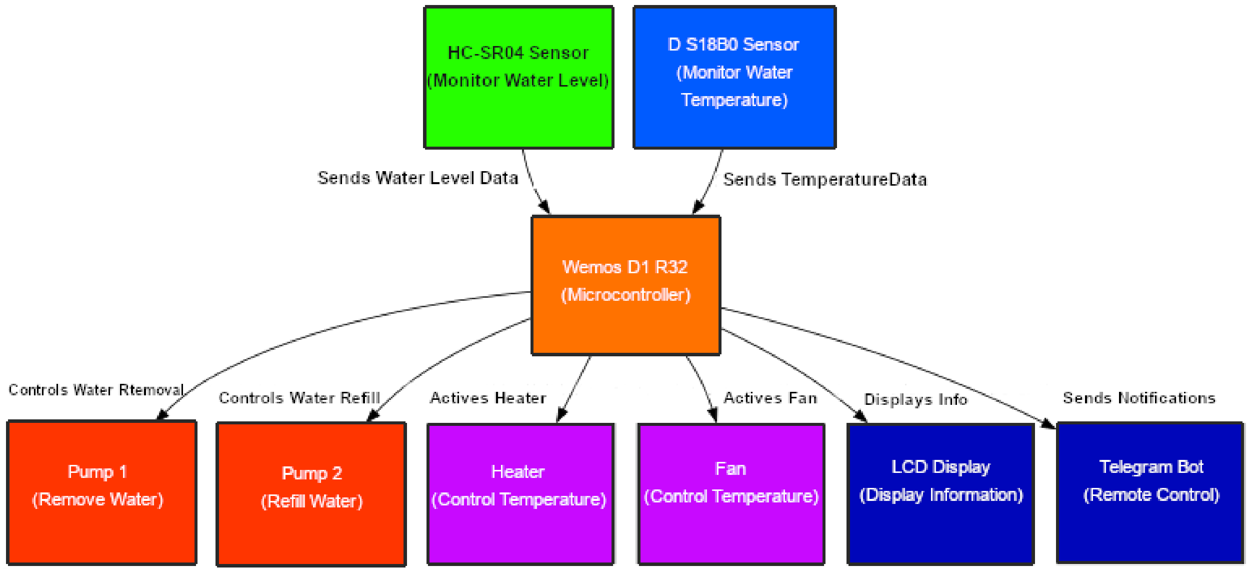
Additionally, the filtration system plays a crucial role in maintaining water quality. The system employs biological and chemical filtration within the chamber filter, combined with a UV light to eliminate algae, bacteria, and viruses, thereby keeping the water clean and safe for the fish. UV light has been proven to be effective in reducing harmful microorganisms, which can otherwise lead to disease outbreaks in aquariums. This setup is designed to support the overall health of the fish, ensuring that water conditions remain optimal even in semi-outdoor environments, where external factors such as temperature fluctuations and exposure to pollutants can pose challenges.

One of the main issues faced by aquarium owners is the inconvenience of performing regular water changes, especially in larger tanks. Manual water replacement not only requires significant time and effort but also introduces the risk of disturbing the delicate balance of the aquarium's ecosystem. The automated water replacement system is designed to address this inefficiency by automating the process and allowing for precise control over water levels.

In the future, the system will be enhanced with additional sensors such as a photodiode to detect water clarity, a pH sensor to monitor water acidity, and further refinement of UV light control within the filtration chamber. An automatic fish feeder is another important component in modern smart aquariums. This device allows fish owners to schedule feeding times and regulate the amount of food given to their fish, reducing the chances of overfeeding or underfeeding. In this system, the automatic feeder can provide dry food such as pellets or vitamin-enriched supplements. Additionally, the feeder serves as a complementary feature to traditional live or wet foods typically given to predator fish, such as small feeder fish, frogs, or mealworms. This ensures a balanced diet that supports the health and growth of predator species.

These enhancements will improve the overall reliability and effectiveness of the system, offering broader benefits for aquarium management beyond predator fish care. Such advancements could provide an even more comprehensive solution for maintaining aquariums, reducing the workload on owners, and ensuring healthier aquatic environments for a variety of fish species.

Figure 1. System Architecture Diagrams of the Smart Aquarium.



Literature Review

1. Internet of Things (IoT) in Aquarium Systems

The Internet of Things (IoT) has rapidly transformed various industries, including aquarium management. By integrating smart technologies into traditional aquarium systems, IoT enables remote monitoring and automation, ensuring that environmental conditions within the aquarium are optimal at all times. IoT allows devices to communicate with one another and provide real-time data to users, who can make adjustments through mobile applications or platforms like Telegram bots. In the case of a smart aquarium, IoT enables monitoring of critical parameters such as water temperature, water level, and even water quality, ensuring a stable and healthy environment for fish.

2. HC-SR04 Ultrasonic Sensor

The HC-SR04 ultrasonic sensor is widely used for non-contact distance measurement, making it ideal for monitoring water levels in aquariums. This sensor operates by emitting ultrasonic sound waves and measuring the time it takes for the waves to return after bouncing off the water's surface. In a smart aquarium system, the HC-SR04 is used to track the water level and trigger automatic water changes. When the water reaches a designated height, such as 20 cm, the system activates Pump 1 to drain water, and when the water level falls to 5 cm, Pump 2 refills the tank.

3. DS18B20 Temperature Sensor

The DS18B20 is a digital temperature sensor known for its accuracy and ease of use. It is widely applied in temperature-sensitive environments, such as aquariums, where maintaining a consistent temperature is critical for the health of fish. The DS18B20 is capable of measuring temperatures within a range of -55°C to +125°C, with an accuracy of ±0.5°C in the range of -10°C to +85°C. In a smart aquarium, the DS18B20 sensor monitors the water temperature and activates either the heater when the temperature falls below 22°C or the fan when it exceeds 30°C. This automated temperature control ensures a stable environment for fish, particularly species that are sensitive to temperature fluctuations.

4. Relay Modules

Relay modules are essential for controlling high-voltage devices such as heaters, fans, and pumps in a low-voltage environment like an IoT-based aquarium system. Relays act as switches, allowing the control of high-power devices through signals from the microcontroller. In a smart aquarium, relay modules are used to manage the activation of both water pumps and temperature control devices based on input from the HC-SR04 and DS18B20 sensors. For instance, relays are activated to start the pumps when the water reaches specific levels or to control the heater and fan based on temperature readings.

5. Water Pumps

Water pumps are fundamental components in a smart aquarium system that require automated water changes. In the smart aquarium described in this study, two pumps are employed: Pump 1 to drain water from the tank and Pump 2 to refill it. These pumps are activated based on the water levels detected by the HC-SR04 ultrasonic sensor. Automated water changes ensure that water is refreshed regularly, which is crucial for maintaining water quality and preventing the buildup of harmful substances such as ammonia.

6. IoT Platform and Telegram Bot Integration

A key feature of this smart aquarium system is its integration with IoT platforms and Telegram bots for remote monitoring and control. By using a Telegram bot, users can check real-time data on water levels, temperature, and system status through their mobile devices. They can also control pumps, lights, and feeders remotely, providing flexibility in managing the aquarium without being physically present. The use of IoT and bots ensures that aquarium owners can respond quickly to any changes in the environment, reducing the risk of harm to the fish.

7. Common Issues in Aquarium Maintenance

Aquarium maintenance is often challenged by several key factors, including water quality, temperature stability, and the control of algae growth. Poor water quality can lead to the accumulation of harmful chemicals such as ammonia and nitrites, which are toxic to fish. Regular water changes and proper filtration are essential for removing these toxins, but manual maintenance can be time-consuming and prone to errors. Additionally, fluctuations in temperature or pH levels can cause stress to the fish, making it harder for them to thrive. These challenges emphasize the need for automated systems like smart aquariums to ensure that water quality remains consistent and fish are provided with a stable living environment.

pH Levels and Fish Health

The pH level of water is a critical parameter in maintaining the health of fish, particularly for species like predator fish that have specific pH requirements. For example, the ideal pH level for freshwater predator fish like channa (snakehead fish) or arowana ranges between **6.5 and 7.5**, which is slightly acidic to neutral. A pH level outside this range can result in stress, weakened immune systems, and even death. Predator fish are especially sensitive to changes in water chemistry, making it important to monitor and maintain stable pH levels in the aquarium. Automated systems can assist in this by using pH sensors to track fluctuations and trigger adjustments such as water changes to restore balance.

Temperature Requirements for Predator Fish

Temperature stability is equally important. For species like channa and arowana, water temperatures should be maintained between **22°C and 30°C**. Temperatures below this range can slow down metabolic processes, while temperatures above 30°C can cause stress and overactivity, potentially leading to health issues. Automated temperature control systems ensure that these fish are always kept in a stable environment by activating the heater or fan when necessary.

8. Algae Growth and UV Sterilization

Algae growth is a common problem in aquariums, particularly when lighting conditions are not properly controlled. Algae can cloud the water, reduce oxygen levels, and create an unattractive appearance. It also competes with aquatic plants for nutrients and can lead to imbalanced ecosystems. The growth of algae is accelerated when aquarium lights are left on for extended periods, especially underwater lights, which promote the development of green algae on glass surfaces and decorations.

In smart aquariums, controlling algae growth is often managed through two mechanisms: regulating light exposure and utilizing **UV sterilization**. By scheduling the lighting cycles or remotely controlling them, users can prevent excessive algae growth. UV sterilizers are highly effective in killing algae spores, as well as other microorganisms such as bacteria and viruses. These devices are commonly integrated into the filtration system and are particularly beneficial in maintaining water clarity and reducing the risk of disease outbreaks.

9. Behavioral Habits and Feeding of Predator Fish

Predator fish like channa or arowana have specific dietary needs, primarily feeding on live prey such as small fish, frogs, or insects like mealworms and crickets. These foods provide essential proteins for growth and energy. In captivity, a mix of live prey and vitamin-enriched pellets is recommended. Automatic feeders in smart aquariums maintain a consistent feeding schedule, preventing overfeeding that can pollute the water. Additionally, predator fish are territorial and need ample space. Overcrowding or poor water conditions can cause stress and aggression. By automating water changes and stabilizing the environment, smart aquariums help reduce stress and encourage healthier behavior.

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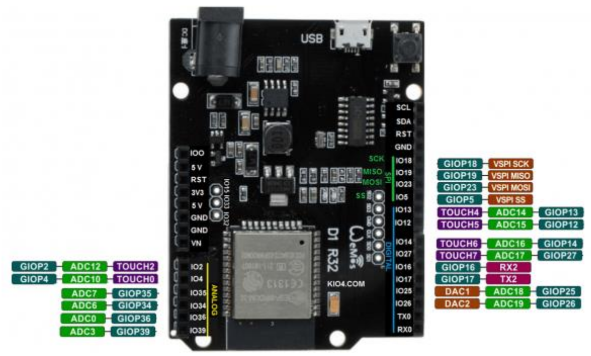
Methodology

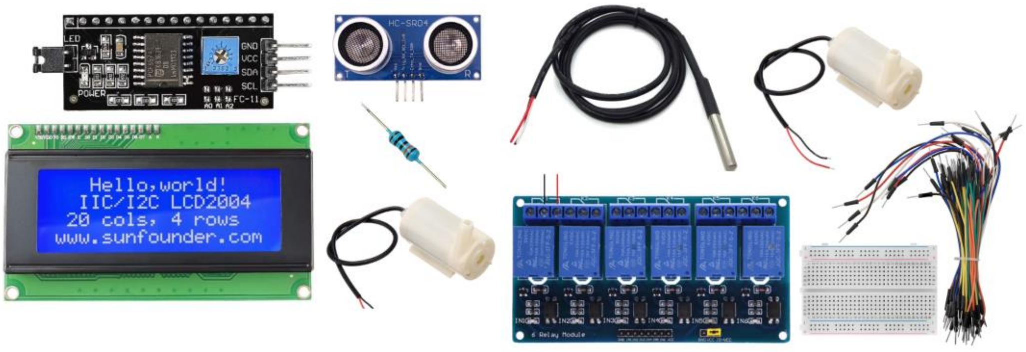
A. Tools and Materials

This smart aquarium system is implemented using the WeMos D1 R32 microcontroller based on ESP32, which is connected to various sensors and actuators through the Internet of Things (IoT) platform. The software is developed using the Arduino programming language with additional libraries such as OneWire for the DS18B20 temperature sensor and NewPing for the HC-SR04 ultrasonic sensor.

Figure 2. Smart Aquarium component.



Aquarium used in this research has dimensions of 39.8 cm in length, 25.4 cm in width, and 28 cm in height, giving it a total water capacity of approximately 28 liters. This size is suitable for small to medium-sized predator fish, allowing sufficient space for swimming while ensuring the necessary water volume for maintaining stable environmental conditions. A variety of tools and materials were employed to construct and operate the smart aquarium system. These include various sensors for monitoring, pumps for water replacement, and control mechanisms to ensure the aquarium's conditions are always optimal. The full list of tools and materials used in this research includes:

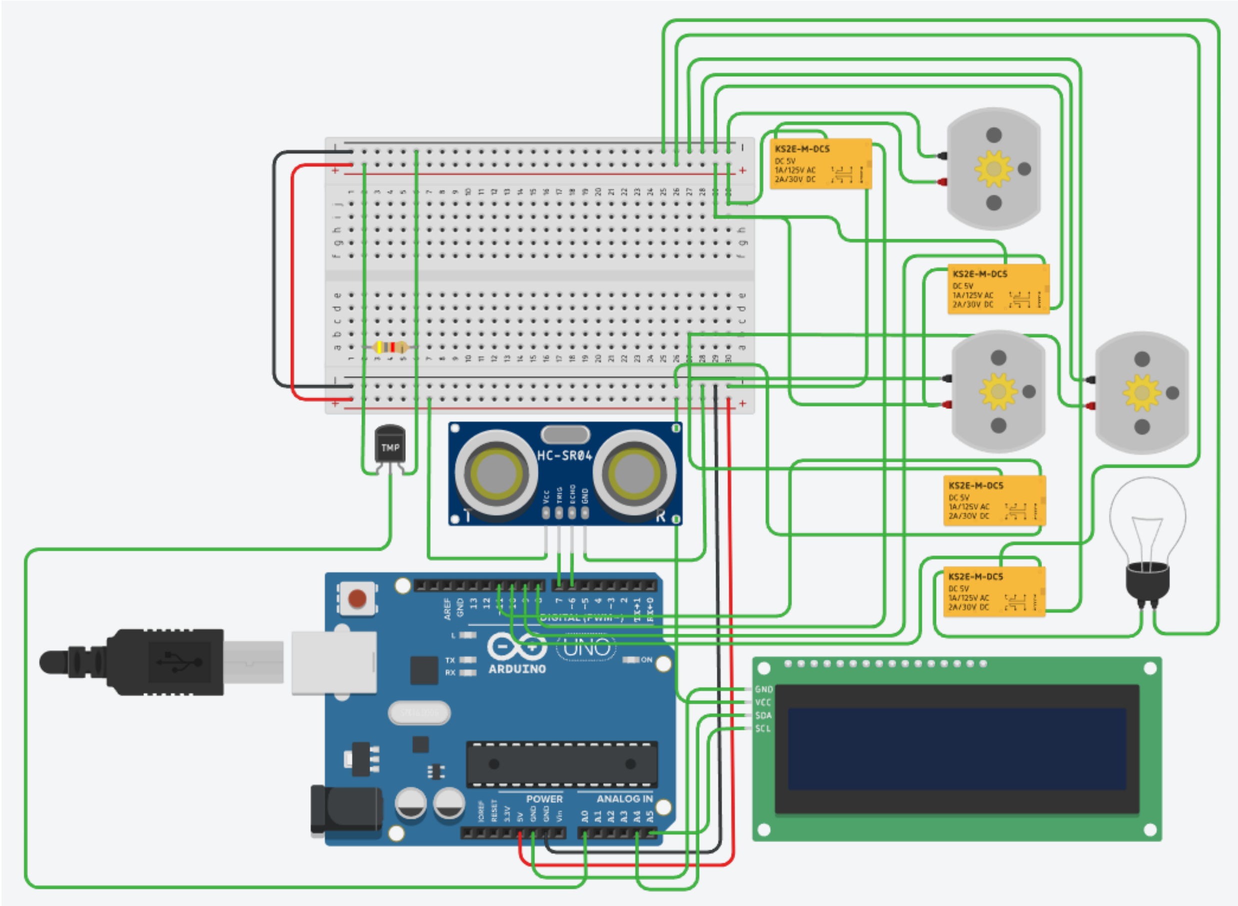


- **HC-SR04 Ultrasonic Sensor**: for monitoring water levels between 5 cm and 20 cm.
- **DS18B20 Temperature Sensor**: for detecting water temperature and activating the heating system or fan.
- **4.75k Ohm Resistor**: as a ½ watt 1% pull-up resistor.
- **6 Channel Relay Module**: used to control Pump 1 (for water removal), Pump 2 (for water refill), a 25 Watt heater, and a 12v DC fan.
- **5v Water Pump**: Pump 1 removes water up to a depth of 20 cm, and Pump 2 refills water up to a level of 5 cm.
- **IoT Platform**: connects the system with a Telegram bot for control and monitoring.
- **20x4 i2c LCD Display**: for displaying information about water conditions.
- **Breadboard & Jumper Wires**: for connecting all components.

B. Prototype Development

This aquarium is designed to allow automatic water replacement and temperature control without manual intervention. The use of pumps for water replacement is designed so that Pump 1 removes water down to a minimum depth of 20 cm, while Pump 2 refills water up to a level of 5 cm. The system is equipped with an ultrasonic sensor to ensure that the water level remains within the predetermined limits. There is no automatic feeding system in this prototype, so the use of a servo is unnecessary. The primary focus of this prototype is on automated water replacement and stable temperature regulation to maintain ideal conditions within the aquarium.

Figure 3. Smart Aquarium system circuit.



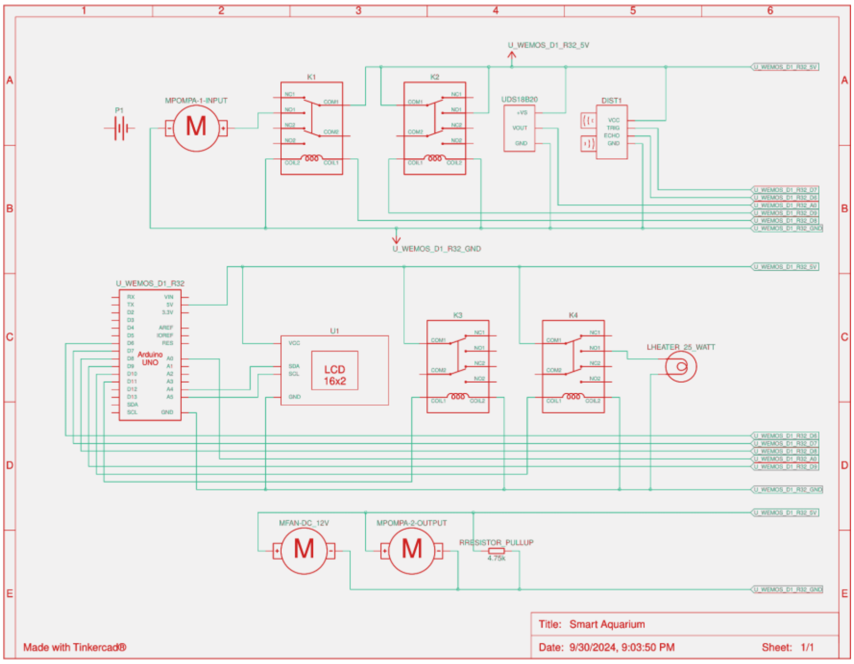
C. Algorithm Implementation

The implementation of this system consists of two main features: water replacement and temperature control.

1. **Water Replacement**
   a. The HC-SR04 ultrasonic sensor measures the water level. When the water level reaches 20 cm, Pump 1 will activate to drain water until it reaches the minimum limit of 5 cm. b. Pump 2 will then be activated to refill the water until the level reaches 20 cm. This process is automatically monitored by the ultrasonic sensor.
2. **Temperature Control**
   a. The DS18B20 sensor measures the water temperature in real-time. If the temperature drops below 22°C, the relay will activate the heater, and if the temperature exceeds 30°C, the relay will activate the cooling fan to stabilize the temperature.

The entire process is controlled through a microcontroller connected to the IoT platform, allowing users to monitor and control the system through a Telegram bot.

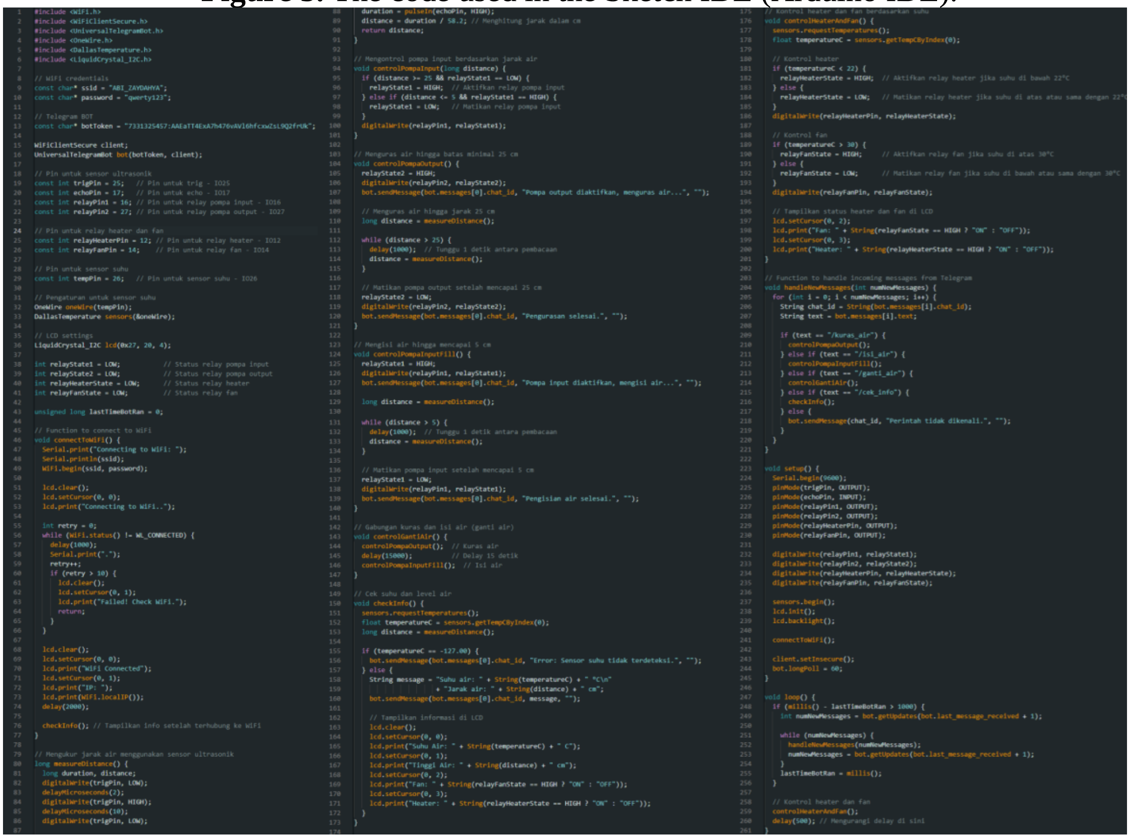
Figure 4. Schematic of the Smart Aquarium system circuit.



D. System Visualization

To aid further understanding, the system is equipped with a block diagram or schematic that shows how the components are interconnected. This diagram includes components such as the ultrasonic sensor, DS18B20 temperature sensor, relays, water pumps, heater, and fan connected to the WeMos D1 R32 microcontroller. This visual illustration will facilitate understanding of data flow and control within the system.

Figure 5. The code used in the Sketch IDE (Arduino IDE).



E. Testing and Calibration

Testing is conducted by measuring the water level and temperature using the connected sensors. Data is collected under different water conditions, such as clear and murky water, as well as varying ambient temperatures. Calibration is performed to ensure that the ultrasonic sensor can accurately measure water levels within the range of 5 cm to 20 cm, and the temperature sensor can detect temperature changes within the range of 22°C to 30°C accurately. The testing process also involves pump control to ensure that both pumps operate according to the desired water level limits. The system is tested under various scenarios to ensure reliability in different conditions.

Figure 6. Object research documentary

F. Testing and Results

After implementing the system, a series of comprehensive tests are conducted to verify that all components function correctly and consistently in line with the design specifications. These tests are crucial to ensure the system's reliability and to identify any potential issues that might affect performance. The testing focuses on two main features: automated water replacement and temperature control, both of which are critical for maintaining a stable and healthy environment for the aquarium’s inhabitants.

The water replacement system is tested under various conditions to assess its responsiveness and accuracy in maintaining the desired water levels, while the temperature control feature is evaluated to ensure it can effectively manage the water temperature within the preset thresholds. Additionally, the system's performance is observed over different environmental scenarios, such as changes in room temperature, to determine its adaptability and resilience. The results from these tests are summarized in the following table, providing a clear overview of the system's efficiency and reliability across all test cases.

Results

This chapter will discuss the findings from the conducted research, which includes automated water replacement, temperature control, and the integration of the IoT system with a Telegram bot for real-time monitoring of aquarium conditions. Data from testing and analysis results are included to support the scientific findings.

A. Testing Results

1. **Water Replacement Testing**
   The water replacement system was tested by monitoring the water level using the HC-SR04 ultrasonic sensor. Pump 1 was activated when the water level reached 20 cm to remove water, and Pump 2 was activated when the water level dropped to 5 cm to refill water.

Table 1. Water Level Testing Results

Initial Condition	Distance Measured by HC-SR04 (cm)	Pump 1 Status (Output)	Pump 2 Status (Input)	Description
Full Water	20 cm	Active	Inactive	Pump 1 is draining water
Decrease	15 cm	Active	Inactive	Water is being drained
Decrease	10 cm	Active	Inactive	Water is approaching minimum
Decrease	5 cm	Inactive	Active	Pump 2 starts refilling water
Filling	10 cm	Inactive	Active	Refilling process is ongoing
Filling	20 cm	Inactive	Inactive	Ideal water level achieved

2. **Temperature Control Testing**
   The temperature control system was tested using the DS18B20 sensor, which activates the relay for the heater if the temperature drops below 22°C and for the fan if the temperature exceeds 30°C. The test results indicate that the system can maintain the water temperature within the specified range.

Table 2. Water Temperature Testing Result

Water Temperature (°C)	DS18B20 Condition	Relay Heater Status	Relay Fan Status	Description
25°C	Normal	Inactive	Inactive	Temperature within normal range
21°C	Cold	Active	Inactive	Heater activated, below 22°C
28°C	Normal	Inactive	Inactive	Temperature within normal range
31°C	Hot	Inactive	Active	Fan activated, above 30°C
22°C	Normal	Inactive	Inactive	Temperature back to normal, all inactive

3. **IoT and Telegram Bot Integration Testing**
   The IoT system controlled via the Telegram bot was tested to ensure that users can monitor the aquarium's condition, including water level and temperature, as well as control the pumps and fans remotely. The system is capable of sending real-time data and providing complete control to users.

Discussion

The discussion also includes an analysis of the test results that compare this system with manual methods. Automated water replacement and temperature control provide increased efficiency and reduce the maintenance burden of the aquarium.

1. **Water Replacement Testing**
   The water replacement system was tested by monitoring the water level using the HC-SR04 ultrasonic sensor. Pump 1 was activated when the water level reached 20 cm to remove water, and Pump 2 was activated when the water level dropped to 5 cm to refill water.
2. **Temperature Control**: The temperature control testing also shows success, with the DS18B20 sensor capable of detecting temperature in real-time and activating the heater or fan according to the specified temperature limits. The system successfully maintains the water temperature within the aquarium in the range of 22°C to 30°C.
3. **IoT Integration**: The integration of the system with the Telegram bot allows for real-time monitoring of aquarium conditions and provides users with the ability to control the pumps and temperature remotely. This offers greater flexibility for users, particularly in monitoring the aquarium without being physically present.

Conclution

This study successfully developed an IoT-based smart aquarium system capable of automating water replacement and temperature control. The tests show that the HC-SR04 ultrasonic sensor can accurately monitor water levels, and the system can control Pump 1 and Pump 2 to maintain water levels within the desired limits (5 cm to 20 cm). Additionally, the DS18B20 temperature sensor has proven effective in detecting water temperature and automatically activating the heater or fan, keeping the water temperature stable within the range of 22°C to 30°C. The system has also been successfully integrated with a Telegram bot, allowing users to monitor and control the aquarium remotely. These findings demonstrate that IoT technology provides a practical and efficient solution for aquarium maintenance. Future developments could enhance this system by adding a photodiode sensor to detect water clarity and a pH sensor to monitor water quality, as well as UV light control in the filter chamber to maintain better water quality.

In the future, this smart aquarium system can be applied beyond the current study, offering a universal solution for aquarium maintenance. Although designed for predator fish, its core functions—automating water replacement and temperature control—can be adapted to different aquarium types. Regular water changes, as facilitated by this system, improve fish health by removing toxins and stabilizing water conditions. With further integration of sensors like pH and water clarity monitors, this system can ensure better water quality, making it a valuable tool for aquarium owners to maintain healthy environments for their fish.

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