IOT BASED WATER QUALITY CONTROL FOR SMALL-SCALE AQUARIUM WITH FUZZY LOGIC

SAFAWATI BINTI ANNUAR

BACHELOR OF COMPUTER SCIENCE (COMPUTER SYSTEMS & NETWORKING) WITH HONOURS

UNIVERSITI MALAYSIA PAHANG

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ID Number : CA20027

Date : JUNE 2023

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WITH FUZZY LOGIC

SAFAWATI BINTI ANNUAR

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ABSTRAK

Abstrak ini memperkenalkan sistem kualiti air yang direka khas untuk akuarium dengan tujuan memastikan persekitaran yang sihat dan berkembang untuk organisma akuatik. Sistem ini menggunakan pelbagai sensor yang terus memantau parameter penting seperti suhu, tahap pH, dan paras air. Data secara langsung dari sensor-sensor ini diproses dan dianalisis menggunakan pendekatan berdasarkan logik kabur (fuzzy logic). Dengan menggunakan fungsi keahlian (membership functions) dan peraturan, sistem logik kabur menilai keadaan kualiti air dan menentukan tindakan yang sesuai untuk mengekalkan keadaan ideal di dalam akuarium. Sistem secara autonomi mengawal elemen-elemen penting seperti penapisan, dan penggantian air, dengan demikian mengurangkan tekanan terhadap kehidupan akuatik dan memudahkan penyelenggaraan akuarium. Kajian eksperimental dijalankan untuk mengesahkan keberkesanan sistem ini, yang menunjukkan keupayaannya untuk terus memelihara piawaian kualiti air yang ideal, meningkatkan kesejahteraan organisma akuatik, dan meningkatkan pengurusan persekitaran akuarium secara keseluruhan.

Secara keseluruhannya, sistem kualiti air untuk akuarium ini menyediakan penyelesaian yang komprehensif untuk memantau dan mengawal faktor-faktor penting, dengan mengekalkan persekitaran yang stabil dan sesuai bagi kehidupan akuatik. Dengan menggunakan teknik logik kabur, sistem ini memberikan pendekatan yang pintar dan automatik untuk mengekalkan keadaan kualiti air yang ideal, dengan akhirnya meningkatkan kesihatan dan keberkesanan persekitaran akuarium.

ABSTRACT

In order to ensure that aquatic organisms have a healthy and prosperous environment, this abstract introduces a water quality system that was especially created for aquariums. The system uses several sensors to continuously track important factors like temperature, pH level, and water level. Real-time data from these sensors is processed and analysed using a fuzzy logic-based methodology. The fuzzy logic system evaluates the water quality conditions and decides on the proper course of action to maintain ideal conditions inside the aquarium using membership functions and rules. The technology automatically controls crucial elements including filtration, and water replacement, reducing stress on aquatic life, and streamlining aquarium maintenance. To demonstrate the system's capacity to continually preserve ideal water quality standards, advance the welfare of aquatic species, and improve aquarium environment management, experimental studies are carried out to confirm its efficacy.

Overall, this aquarium water quality system provides a thorough way to keep track of and regulate key variables, maintaining a stable and favourable environment for aquatic life. The system offers an intelligent and automated method for maintaining ideal water quality conditions, eventually improving the health and vitality of the aquarium environment. It does this by utilising fuzzy logic principles.

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LIST OF ABBREVIATIONS

IoT	Internet of Things
DHT	Digital Humidity and Temperature
MQTT	Message Queuing Telemetry Transport
API	Application Programming Interface

CHAPTER 1

INTRODUCTION

1.1 Introduction

The diversity of life on our planet depends critically on aquatic environments, which also keep the delicate balance of its biodiversity. However, a result of pollution and human activity, the water quality in these ecosystems is constantly in danger. Aquatic life depends on the presence of clean, adequate water conditions for its survival (Vigil, K. M., 2003). Therefore, it is crucial to implement quality water management strategies that are intended to safeguard and improve the aquatic environment.

In order to protect the wellbeing and long-term sustainability of aquatic ecosystems, this project intends to investigate the idea of smart quality water for aquarium. The use of cutting-edge technologies and data-driven strategies to monitor, evaluate, and regulate water quality indicators that are essential for the wellbeing of aquatic species is referred to as "smart quality water for aquarium" (Bachmann, N., 2002). In order to guarantee the ideal water conditions for the survival and flourishing of aquatic life forms, it comprises the integration of sensor networks, real-time monitoring systems, and data analytics.

An IoT based water quality for control small-scale aquarium with fuzzy logic can provide several other advantages in addition to the more obvious ones of preserving a healthy aquatic environment. For aquarium owners, these potential advantages include peace of mind and a reduction of worry because they know the system is always monitoring and maintaining ideal water conditions. Because of the system's automated and real-time monitoring capabilities, users may enjoy their aquarium without having to worry about the water's condition all the time. Additionally, a well-kept aquarium may be a peaceful and aesthetically beautiful addition to the house, adding to a relaxing ambiance and possibly improving everyone in the family's general well-being without having to worry about the water's condition all the time. Additionally, a well-kept aquarium may be a peaceful and aesthetically beautiful addition to the house, adding to a relaxing ambiance and possibly improving everyone in the family's general well-being.

Numerous advantages are provided by fuzzy logic, a mathematical strategy for dealing with uncertainty and imprecision, in a variety of contexts. Fuzzy logic has several key benefits, including the capacity to handle ambiguous and complex input, which enables more accurate simulation of real-world systems. Fuzzy logic enables decision-making procedures that imitate human reasoning by combining linguistic variables and fuzzy sets, resulting in more intuitive and user-friendly solutions (Jager R, 1995). Fuzzy logic is particularly useful in fields like artificial intelligence, control systems, pattern recognition, and decision support systems due to its versatility, as these fields may not always be able to adequately capture the complexity of a given problem using exact and rigid rules. Fuzzy logic is an efficient instrument for solving practical issues and enhancing the precision and efficacy of decision-making processes because of its versatility and capacity to handle ambiguity.

This project's background part examines the literature on smart water technology meant to safeguard aquatic life and provides an overview of the problems with water quality in aquatic ecosystems. It looks at several elements, including as temperature changes and fish waste pollution, that contribute to the deterioration of water quality. The literature review highlights the developments in smart water technologies, which include three important sensors the DS18B20 Temperature sensor, the pH quality water sensor, and the water level sensor along with remote monitoring systems and classification modelling. The evaluation and administration of water quality for home aquariums has been completely transformed by these advancements. In this context, it will also be investigated how fuzzy logic, MQTT, WebSocket, and API integration can be used to improve the functionality and connectivity of the water quality system for aquarium based on the IoT architecture of IoT based water quality control for small scale aquarium with fuzzy logic.

1.2 Problem Statement

The problem is an insufficient aquarium water quality management system, which creates unsafe conditions for aquatic life. The absence of a thorough and effective system to guarantee the provision of clean, balanced, and adequate water conditions within aquariums is the root cause of this issue. The problem is an insufficient aquarium water quality management system, which creates unsafe conditions for aquatic life. The absence of a thorough and effective system to guarantee the provision of clean, balanced, and adequate water conditions within aquariums is the root cause of this issue (Wimalawansa, S. J., 2013).

The removal of metabolic wastes, uneaten food, and other organic compounds produced inside the aquarium might be hampered by inadequate biological filtration systems or by inadequate maintenance of current systems (Sanders, E., 2019). The build-up of these materials can result in a decline in water quality, an increase in ammonia levels, and the spread of dangerous bacteria, endangering the wellbeing of aquatic life (Van, WYK., 1999). Others, water quality problems are frequently not detected right away or are not swiftly resolved, which exacerbates their detrimental effects on aquatic life. Caretakers of aquariums may overlook slight changes in water quality in the absence of reliable monitoring systems and early warning systems, causing issues to worsen and possibly kill the aquatic life such as fish in ways that are irreversible.

The existence, health, and well-being of aquatic organisms depend on maintaining the highest possible water quality conditions in aquariums (Karydis, M., 2011). This project not only recognizes the significance of optimal water quality but also aims to actively contribute to the preservation and conservation of these species. This research aims to make a significant contribution to the sustainability of aquatic ecosystems by creating a favourable habitat that promotes their longevity and reproductive success. It recognises the interdependence of these organisms on their surroundings and works to foster conditions that will enable them to flourish and enhance biodiversity. This project seeks to provide a secure and nurturing environment for aquatic organisms, contributing to their well-being and the more general objectives of species preservation and ecosystem conservation. It does this through meticulous monitoring, analysis, and implementation of effective water quality management strategies.

1.3 Objective

The objective of this project are:

i. To study the requirement for IoT architecture to monitoring the quality of water by establish the data to collect and analyze real-time data.

ii. To develop a water quality system for aquarium with fuzzy by maintaining the best possible water quality by create the procedures for routine water changes if the aquarium caretakers get the alarm from the notification.

iii. To evaluate the effectiveness of maintaining the ongoing observation and evaluation of the water quality data.

1.4 Scope

The scope of the project consist of user, system and development. The scopes are specified as below:

User Scope:

i. Aquarium hobbyists at Pekan, Pahang.

System Scope:

i. The sensors that use to collect the data which are the pH quality of water, the degree temperature of water and the level of water.

ii. Give an alert when the water quality is in high polluted.

iii. To classify water quality using fuzzy logic with three variables (pH, temperature, and distance of water level), we can determine if the water quality is normal when the pH is neutral, temperature is normal, and water level is normal. The communication protocol that will be used is MQTT and WebSocket

Development Scope:

i. Develop using Arduino IDE to collect the data from 3 sensors which are pH sensor, DS18B20 sensor and ultrasonic sensor.

ii. From the 3 variable data will be stored in ESPDuino32 and will send the data to the web server, MQTT server, WebSocket server and AI server.

iii. The system will use Laravel framework, Visual Code Studio and VNC.

1.5 Thesis Organization

This thesis consists of five chapters. Chapter 1 shall discuss on the introduction, problem statement, objective the scope and thesis organization of the project.

Chapter 2 generally explain and discuss about the literature review study on existing system that similar with water quality system.

Chapter 3 will explain about the design that contain the architecture design, dashboard design and analytic feature design of the system.

Chapter 4 will explain the result and discussion. This chapter will discuss the implementation of the project and result of the project.

Lastly, chapter 5 will conclude all the chapter from chapter 1 until chapter 4 about Water Quality System for Aquarium. There is also brief explanation of current project that can be improve in future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review is a crucial part of every research project because it offers a thorough overview of the body of information, theories, and studies that have been done on the research issue. By stressing the need for additional research and pointing out gaps in the existing literature, this chapter serves as a basis for the existing system which focusing on their architecture and main function of the application and the benefits of water quality system. This existing project comparison indicates the strength and efficacy of the existing application.

2.2 Existing Systems/Works

2.2.1 Development of Automated Real-Time Water Quality Monitoring and Controlling System in Aquarium

The increased demand for seafood, especially fish, is driving the rapid growth of the aquaculture business. Fish farming has grown to be a substantial economic contributor, and one technique that is gaining popularity is raising fish in big tanks (Yasruddin, M. L., 2022). For the fish's health and the prevention of infections, it is essential to keep the water quality in these tanks at an acceptable level (Yasruddin, M. L., 2022). Manual water quality monitoring and management can be difficult and time-consuming.

This research suggests an automated fish farming water quality control system (Yasruddin, M. L., 2022). The system consists of a server, a mobile application, a microcontroller, and different sensors. The sensors continuously track the characteristics of the water, and the microcontroller processes the data before sending it to a server for evaluation. Farmers can get real-time information and remotely operate the system using the smartphone application (Yasruddin, M. L., 2022).

A sump tank connected to the main aquarium makes up the suggested system design; it provides additional space for filtration equipment and boosts water volume for stability. The sump tank contains distinct parts for mechanical, biological, and chemical filtration before returning the filtered water to the main aquarium through an overflow portion (Yasruddin, M. L., 2022). Sensors that detect variables like ammonia, nitrites, nitrates, dissolved oxygen, pH, temperature, electrical conductivity, total dissolved solids, and turbidity are used to monitor the quality of water (Yasruddin, M. L., 2022). A microprocessor analyses the data, and when any parameter exceeds predetermined thresholds, the corresponding actuators are engaged to take the necessary corrective action.

The server and a mobile application make up the system software design. The server receives and analyses sensor data, using MySQL to manage and organise the data. On the server, the gathered data is immediately stored, processed, and updated. Then, using the HTTP protocol, the processed data is delivered to the mobile application (Yasruddin, M. L., 2022). Users of the mobile application can access a menu that shows all the data related to water quality as well as real-time graph visualisations of their chosen data. Users also have the option of directly controlling the system and customising the data to suit their tastes. This two-part software architecture allows for effective system control and user-friendly data processing, storage, and visualisation (Yasruddin, M. L., 2022).

In conclusion, this research suggests an automated fish farming water quality control system that takes important fish health indicators into account. The monitoring and control procedure will be made simpler by the system, which will help the aquaculture sector and guarantee the welfare of farmed fish (Yasruddin, M. L., 2022).

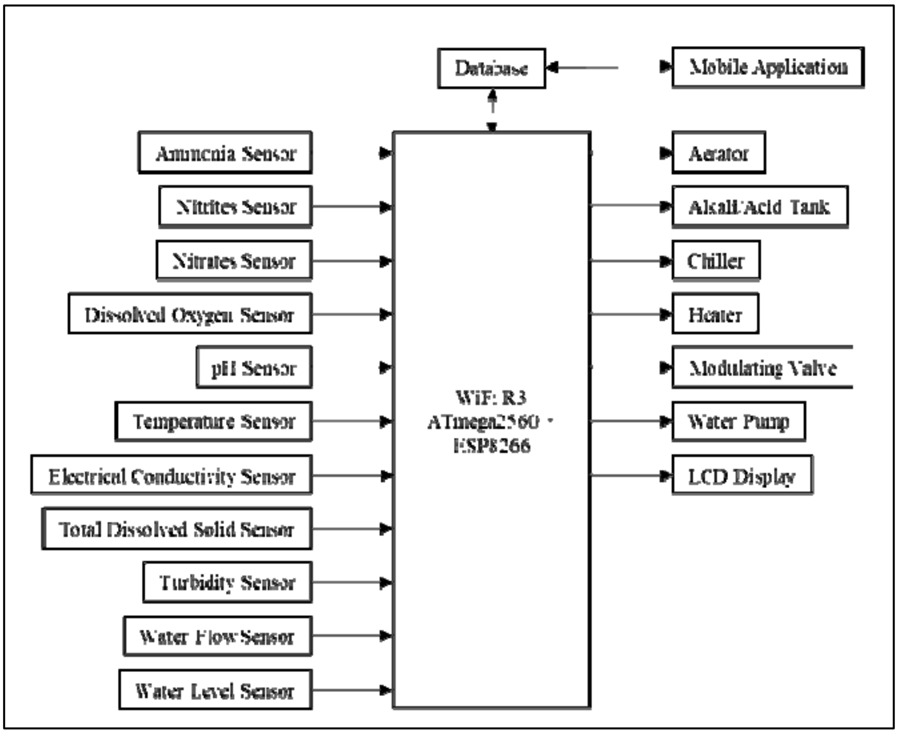

Figure 2.1: Block Diagram

2.2.2 Water Quality Monitoring System with Parameter of pH, Temperature, Turbidity, and Salinity Based on Internet of Things

In addition to being crucial for human survival, clean water also significantly enhances the quality of life and the health of the environment. Its significance is seen in a variety of industries, including fisheries, where many people have turned to keeping aquariums full with decorative fish to pass the time during the pandemic (Adityas, Y., 2021). However, keeping aquarium water quality is essential, considering elements like temperature, pH, turbidity, and salinity. An IoT-based water quality monitoring system has been created to make sure the water satisfies the necessary requirements in order to meet this need (Adityas, Y., 2021).

The monitoring system makes use of several sensors, including the pH, salinity, turbidity, and temperature sensors (DS18B20) (Adityas, Y., 2021). These sensors gather information on important characteristics and instantly transmit it to a centralised database. Users can view the gathered data on an internet dashboard at any time to keep track of the water quality. The capacity to monitor in real-time makes it possible to quickly identify any deviations from the intended water quality requirements.

The findings of earlier study in this area have been encouraging. For instance, research has shown that utilising the TSD-10 sensor to detect turbidity levels is accurate and reliable (Adityas, Y., 2021). The DS18B20 sensor has been successfully used in research to monitor water temperature, and it has shown effectiveness in delivering real-time information and activating automated control systems to maintain ideal conditions (Adityas, Y., 2021). Like this, farmers have gained important knowledge about the compatibility of water for plant species by measuring pH levels in aquaponic water using an Arduino Uno microcontroller.

The water quality monitoring system ensures efficient and effective monitoring of aquarium water by using IoT technologies. This not only enhances the health of the fish but also gives consumers the ability to act quickly to address any deviations from the normal parameters for water quality (Adityas, Y., 2021). Overall, the system provides a trustworthy and simple method for checking and maintaining the water quality in aquariums, allowing users to take pleasure in their fishkeeping pastime while preserving a thriving aquatic ecosystem.

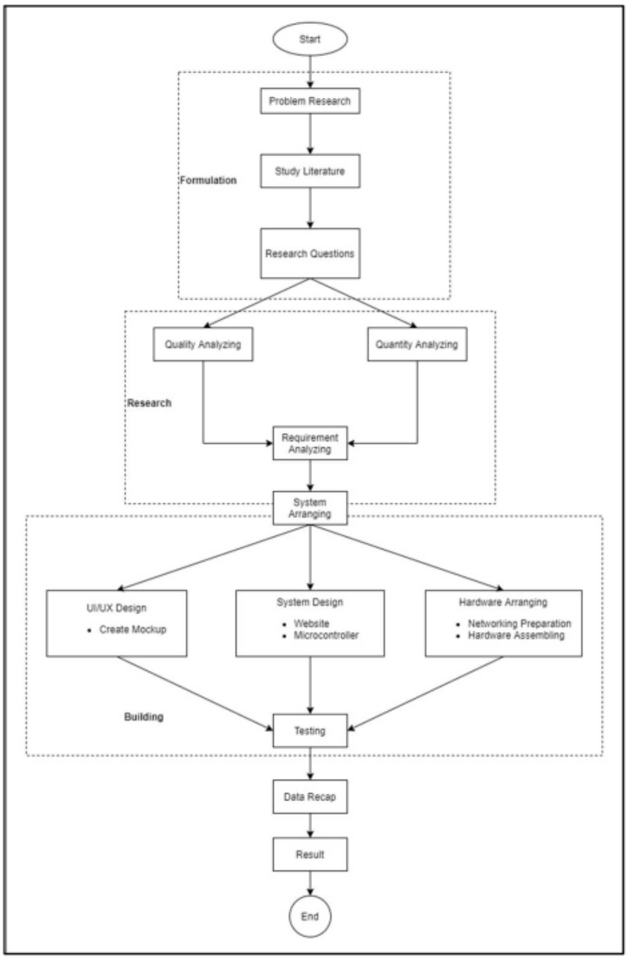

Figure 2.2: Architecture

2.2.3 Automatic Drain System in Seawater Aquarium with Fuzzy Logic Method

More than 700 different kinds of marine ornamental fish can be found in the waters off Indonesia. Around 75% of the world's supply of ornamental saltwater fish comes from this nation (Adin, N, 2020). Water quality is crucial for effectively maintaining these marine ornamental fish. As these fish are extremely sensitive to environmental circumstances, the quality of the water has a significant impact on their growth and development.

Temperature, salinity, pH (acidity), dissolved oxygen (DO), turbidity, ammonia, nitrate, and carbonate are a few of the variables that need to be considered when regulating the water quality of saltwater ornamental fish (Adin, N, 2020). The need of keeping proper water conditions for ornamental fish kept in seawater has been emphasised by researchers because variations from the recommended values can be harmful to the fish's health (Adin, N, 2020).

Unfortunately, a lot of people who keep ornamental fish in sea water are not familiar with the recommended values for optimum water quality (Adin, N, 2020). Water changes are frequently made without considering crucial readings like temperature and pH until the water becomes visibly murky (Adin, N, 2020). However, both low and high temperatures or pH levels can have a detrimental effect on the health of aquarium ornamental fish.

The introduction of smart aquarium systems utilising the Internet of Things (IoT) is one example of how technology has advanced to meet this issue. A system that has been developed includes sensors to gauge the pH and temperature of the tank, which are then used as inputs for a fuzzy logic-based system (Adin, N, 2020). The system can identify certain situations in the water parameters thanks to the fuzzy logic method, which enables the system to make decisions based on several data groups and handle complicated computations. The system is capable of tasks that need decision-making akin to that of a human by utilising artificial intelligence principles (Adin, N, 2020). The device automatically starts an aquarium water change if the water quality deviates from the set parameters.

In conclusion, preserving the water quality is essential for the survival of marine ornamental fish. Fuzzy logic-based IoT-based smart aquarium systems provide a technologically advanced method for automatically monitoring and altering water quality parameters to maintain a suitable habitat for ornamental fish that live in seawater.

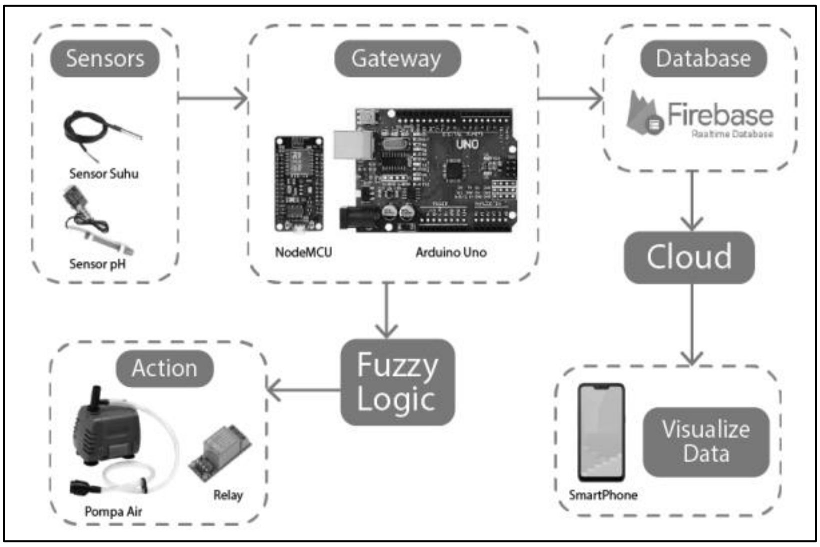

Figure 2.3: Architecture System

2.3 Analysis/ Comparison of Existing System

2.3.1 Analysis of comparison on existing system.

Table 2. 1: Comparison of Existing System

System Title	Advantages	Disadvantages
Development of Automated Real-Time Water Quality Monitoring and Controlling System in Aquarium (Yasruddin, M. L., 2022)	1. Continuous and real-time monitoring of water quality parameters is provided by the system, ensuring quick identification of any deviations or irregularities. 2. The system delivers accurate measurements of variables like pH, temperature, turbidity, and salinity by utilising sensors and automation, which lowers human errors in manual monitoring. 3. To maintain ideal conditions for fish and aquatic life, the system can be built to automatically modify parameters, such as temperature or pH. 4. Rapid detection of any abrupt alterations or anomalies in water quality enables prompt corrective action to avoid harm to aquatic species. 5. The technology makes it less necessary for aquarium owners to manually monitor and	1. Investing in sensors, controllers, and networking infrastructure is necessary for the implementation of an automated real-time water quality monitoring and regulating system, which can be expensive. 2. The system's setup and maintenance may call for technical knowledge and abilities, restricting its accessibility for people with little technological know-how. 3. The system depends on sensors, controllers, and communication networks operating correctly. Its performance might be impacted by any technological issues. 4. Careful planning is necessary when designing and integrating the system's components, such as the sensors, controllers, and actuators. Complex configurations may also be necessary.

	intervene, increasing their level of convenience.	
Water Quality Monitoring System with Parameter of pH, Temperature, Turbidity, and Salinity Based on Internet of Things (Adityas, Y., 2021)	1. The IoT-based system gives users the freedom and convenience to remotely monitor water quality metrics via linked devices. 2. Constant data collection and analysis allow users to learn important information about trends and patterns in water quality, which helps with aquarium management decision-making. 3. When water quality metrics surpass predetermined levels, the system can send users real-time alerts or notifications, allowing for prompt interventions. 4. Depending on the unique requirements of the aquarium, the IoT architecture enables the extension and integration of new sensors or services.	1. The system significantly depends on a steady and dependable internet connection. Connectivity reliability. The real-time monitoring and control capabilities may be impacted by any network outages or connectivity problems. 2. Data security and privacy issues are raised when data concerning water quality is transmitted online. To protect sensitive information, appropriate safeguards must be put in place. 3. Configuring sensors, establishing connectivity, and assuring component compatibility are all steps in the setup of an IoT-based system that may call for technical know-how. 4. Setting up an IoT-based system might be expensive up front, what with having to buy sensors, build out the networking infrastructure, and pay for continuous maintenance.
Automatic Drain System in	1. Precise control of draining operations in response to water	1. Because the fuzzy logic method depends on predetermined rules and

Seawater Aquarium with Fuzzy Logic Method (Adin, N, 2020)	quality circumstances is made possible by the fuzzy logic method, which enables more nuanced decision-making based on the inputs from multiple sensors. 2. The fuzzy logic approach can adapt to diverse aquarium configurations and varying water quality levels, enabling system changes based on needs. 3. The system automatically modifies the drain system in accordance with the specified fuzzy logic rules after continuously analysing real-time data from sensors. 4. Reduced need for manual draining based on visual observations thanks to automation of the drain system, which saves time and labour.	membership functions, it may not be able to handle complicated or unforeseen events. 2. The precision and decision-making of the system can be impacted by minute variations or inaccurate sensor readings. 3. The system might not consider variables that call for human judgement or extraordinary circumstances that might call for manual intervention.

2.3.2 Relevance of comparison with Quality System for Aquarium

The comparison of these three journals with an aquarium water quality system is relevant since they all offer information on various techniques and tools for observing and managing water quality in aquatic environments. Individuals working in aquarium management can decide on the best water quality system for their unique requirements by reading and comparing these articles.

The first journal emphasises the significance of ongoing monitoring and exact control of water parameters while discussing the creation of an automated real-time water quality monitoring and regulating system. Aquarium hobbyists who desire to maintain ideal water conditions for the health and wellbeing of their aquatic species may find this information to be useful. The journal offers insightful information about the advantages of in-the-moment data analysis and quick reaction to water quality anomalies, enabling timely action to provide a stable and healthy environment for the aquarium residents.

The second journal focuses on an Internet of Things (IoT)-based system for monitoring water quality. In the connected world of today, where remote monitoring and data visualisation are becoming more and more significant, this magazine is pertinent. Aquarium owners can obtain real-time data, get alerts about parameter deviations, and remotely monitor their tanks by incorporating IoT technology with water quality monitoring. For people who frequently travel or who have big aquarium systems that need constant monitoring, this strategy is especially helpful.

The third journal provides a fuzzy logic-based automatic drain system for a seawater aquarium. By carefully controlling water changes, this method has the advantages of automation and water/energy savings. The importance of this magazine can be attributed to its emphasis on enhancing water quality using automated methods, which is useful for aquarium owners who seek to achieve ideal water conditions without manual involvement. The fuzzy logic approach enables intelligent decision-making based on specified guidelines, which contributes to a more consistent and reliable environment for the residents of the aquarium.

Comparing these three journals offers a thorough overview of the various methods and tools available for observing and managing the water quality in aquariums. It enables those who are interested in aquariums to weigh the benefits and drawbacks of each system while considering elements like real-time monitoring, remote accessibility, automation, and energy efficiency. People can choose a water quality solution that best suits their unique aquarium setup and requirements by taking the information from these journals into consideration.

2.4 Summary

To get a thorough understanding of marker tracking techniques, the literature research for the proposed project comprised a thorough assessment of publications, journals, and academic resources. The researchers were able to determine and assess the best methods for precisely and consistently tracking markers thanks to this review. The strengths, weaknesses, trends, problems, and developments in marker tracking technology were discovered by analysing the body of existing literature, enabling the choice of the most suitable approaches for the project to be made with knowledge. The assessment also assisted in identifying research voids and topics for additional investigation, directing the proposed project towards potential innovative insights and marker tracking enhancements. Overall, the literature evaluation was helpful in determining the direction of the research, setting a strong theoretical framework, and guiding the project's methodology.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Key components of the technique for the aquarium water quality system include system design, dashboard design, data analytic, and its potential use of propose solution. These components are essential for creating a practical and simple method for monitoring and maintaining the best possible water quality in aquariums. The system's design is centred on developing a dependable and effective method for keeping track of vital water factors like temperature, pH level and water level. Users of the dashboard design will be able to examine real-time water quality data and receive notifications for any changes from the expected conditions through a simple and straightforward interface.

Data analysis entails creating algorithms to analyse the gathered data, spot trends, and offer perceptions into the general wellbeing of the aquarium ecosystem. This analysis can assist aquarium keepers or owners in taking the proper steps to maintain a healthy and balanced habitat, such as modifying filtration, adding vitamins, or making water changes. To maintain the welfare of aquatic life in their tanks, aquarium hobbyists, professionals and even commercial institutions may employ the proposed water quality system for aquariums. The device can aid in fostering an aquarium environment that is healthy and lively by closely monitoring water conditions and acting quickly in case there are any problems.

3.2 Flowchart

The sequential flow and operation of the complete system are shown visually in a flowchart. It is a useful tool for improving comprehension and visualising difficult procedures. The sequential system procedures are depicted in the flowcharts supplied below. These flowcharts make it possible to see each stage clearly, which improves comprehension of the overall operation of the water quality system and the connections between its numerous components. Using flowcharts, stakeholders can ensure smooth coordination and effective management while also easily understanding the system's complex procedures.

Figure 3.4: Water Quality for Aquarium

The flowchart for the water quality system begins with the ESPDuino32 microcontroller. From there, the flow moves to the ultrasonic sensor, which is responsible for reading the water level data. If the distance between the water level and the water base is less than 10cm, the system proceeds to read the pH data.

To achieve the desired voltage for pH 7, strive for 2.5V when adjusting the potentiometer on the pH sensor module. Continually check the pH sensor's voltage output while changing the potentiometer until a reading of 2.5V is obtained, confirming pH 7 calibration success. By comparing voltage measurements to known pH values acquired during calibration, the pH sensor can properly measure pH levels in a variety of solutions once calibration is complete. When the pH data is below 6 or above 8, the system moves on to read the temperature data.

Upon reading the temperature data, if it falls below 23 degrees Celsius or exceeds 27 degrees Celsius, the pump is activated to pump out the water from the aquarium. Simultaneously, an alert is sent via Telegram to notify the user about the situation. Once the water level distance is within the range of 11-19cm from the water base, the pump that removes water is turned off.

However, if the water level distance is more than 20cm from the water base, the system activates the pump to supply water back into the aquarium. This process ensures that the water level is maintained within the desired range, preventing both excessive depletion and overflow.

By following this flowchart, the water quality system can effectively monitor and regulate the water level, pH, and temperature parameters within the aquarium, ensuring optimal conditions for the aquatic life while providing necessary alerts and control mechanisms.

3.3 Architecture Design

In order to successfully monitor and manage the water conditions in an aquarium, the architecture design of the aquarium water quality system is crucial. It entails integrating several parts and technology, including sensors for measuring important factors like temperature, pH, and water level, as well as a central unit for data processing. The design prioritises connectivity and enables real-time monitoring via wireless or network transfer of data to a user interface or central monitoring station. Additionally, automation tools may be included to set off alerts or modify filtering processes in response to changes in water quality. An effective data gathering, processing, and control system allows aquarium owners to maintain the best water quality for the welfare of their aquatic species.

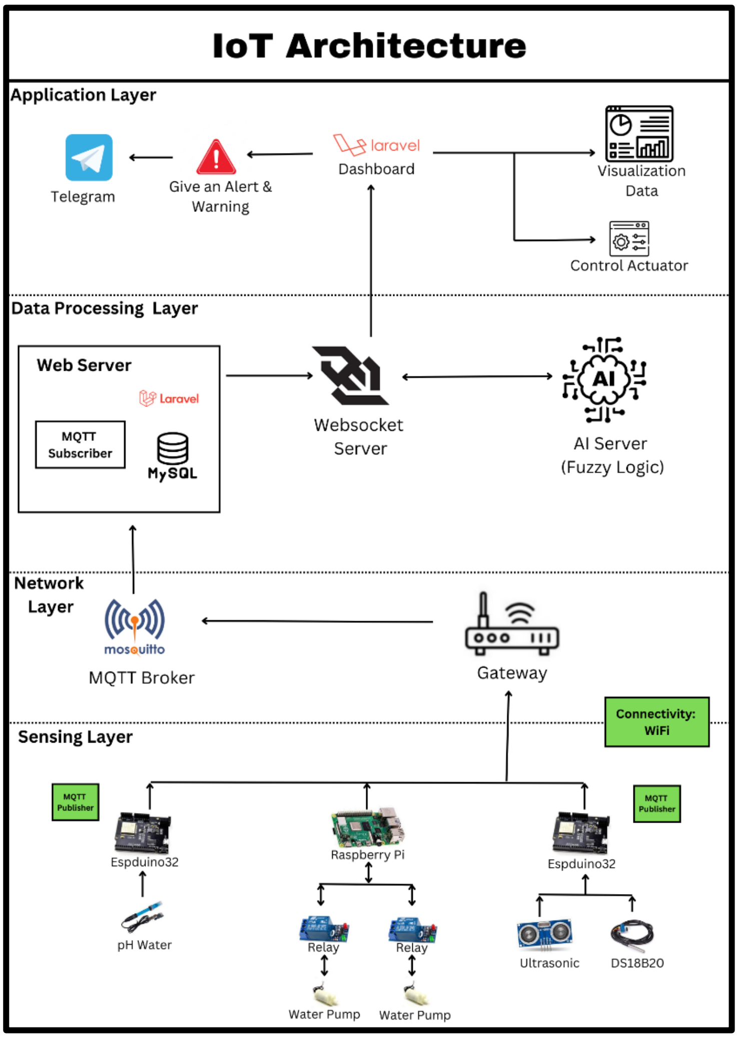

Figure 3.5: IoT Architecture Water Quality System

The ESPDuino32 microcontroller oversees keeping track of significant parameters using a pH sensor, temperature sensor, and ultrasonic sensor at the sensing layer of the water quality system. The ESPDuino32 can gather vital information from these sensors about the pH levels, water temperature, and water level inside the aquarium. The ESPDuino32 connects to the MQTT Broker via its built-in Wi-Fi connectivity, allowing for the seamless transmission of the acquired data. The ESPDuino32 makes use of this wireless connection to guarantee that the real-time sensor data is reliably stored on the MQTT Broker, establishing a central location for additional analysis and management. This configuration makes it possible to monitor the water quality continuously and precisely in the aquarium, providing the groundwork for further management and decision-making procedures inside the system.

The water quality system for an aquarium uses a Wi-Fi connectivity strategy in the network layer. ESPDuino32 sends the gathered data to a MQTT broker via a gateway in its capacity as a MQTT publisher. For effective communication between devices, IoT applications frequently use the lightweight messaging protocol MQTT. The MQTT broker acts as a central hub for receiving and processing the data, and the ESPDuino32 may use MQTT to communicate water quality data consistently and securely to it. This network layer makes sure that data is seamlessly transferred from the sensor layer to the data processing layer, allowing for additional analysis, visualisation, and potential interaction with other systems or applications for thorough water quality monitoring and management in the aquarium.

The MQTT subscriber is essential for receiving data from the MQTT broker in the data processing layer of the aquarium water quality system. Following that, the information is kept organised and persistently stored in a web server. A WebSocket server that supports real-time communication and data sharing with other connected devices or apps also stores the data. The data is sent from the WebSocket server to an AI server for additional processing. The data is classified by the AI server, which enables the system to create rules and patterns based on the measured water quality indicators. Making knowledgeable decisions about the maintenance and control of the aquarium's water quality is aided by this examination. The MQTT subscriber is essential for receiving data from the MQTT broker in the data processing layer of the aquarium water quality system.

Following that, the information is kept organised and persistently stored in a MySQL database server. A WebSocket server that supports real-time communication and data sharing with other connected devices also stores the data. The data is sent from the WebSocket server to an AI server for additional processing. The data is classified by the AI server, which enables the system to create rules and patterns based on the measured water quality indicators. Making knowledgeable decisions about the maintenance and control of the aquarium's water quality is aided by this examination.

A Laravel-based dashboard is used in the application layer of the aquarium water quality system to offer a user-friendly interface for visualising the collected data. The dashboard allows users to quickly monitor the water quality parameters of the aquarium by presenting the data in a relevant and instructive way, such as graphs, charts, and statistics. Users can also alter system settings and parameters on the dashboard's dedicated control page, giving them the power to actively manage and maintain the water quality. Furthermore, the system includes an alarm status feature to guarantee timely notifications. The system sends the user an alert message via the Telegram messaging service if an abnormal circumstance or threshold violation happens. This proactive alert system enables users to quickly address any water quality problems in the aquarium and take the necessary steps to maintain a healthy habitat for the aquatic life.

3.4 Data Collection

The data will be collected depend on fuzzy logic classification. The data will collect from pH of water, the temperature of water and the level of water. The sensors that will use to collect the data are pH sensor, DS18B20 sensor and ultrasonic sensor.

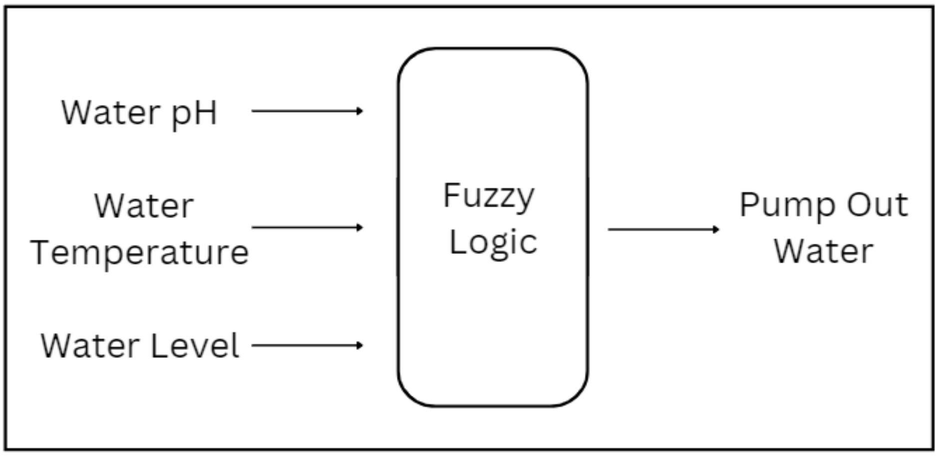

Figure 3.6: Implementation of Fuzzy

The application of fuzzy logic for water temperature and pH sensors is shown in Figure 3.6. The application of fuzzy logic is then done using the fixed data that was retrieved from this store. The membership function, which assigns degrees of membership to linguistic concepts like "cold", "normal", and "hot" for temperature as well as "acidic", "neutral," and "alkaline" for pH, and “high” and “normal” processes the input to the fuzzy logic system. The output of the fuzzy logic system determines whether to operate the water pump, signalling whether it is necessary based on the membership values. The efficient control and decision-making procedures for managing water systems based on temperature and pH conditions are made possible by this use of fuzzy logic.

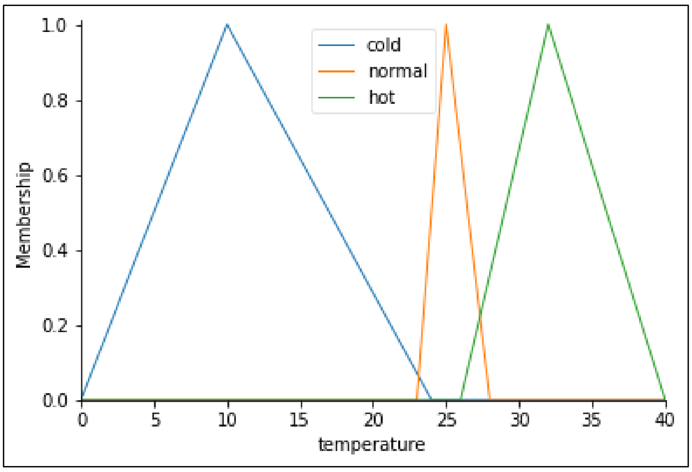

Figure 3.7: Membership Function of Temperature

The membership function of temperature is representation used in fuzzy logic to indicate the level of membership or likelihood of an element belonging to a specific set, is shown in the figure 3.7. In this instance, the temperature is broken down into different linguistic categories like "cold", "normal", and "hot" (Adin, N, 2020). Higher values mean a stronger affiliation to a particular linguistic word, with the form and slope of the curves showing the transition between these terms. With the use of this membership function, the temperature of water can be modelled and reasoned about in fuzzy logic systems, facilitating more adaptable and complex decision-making.

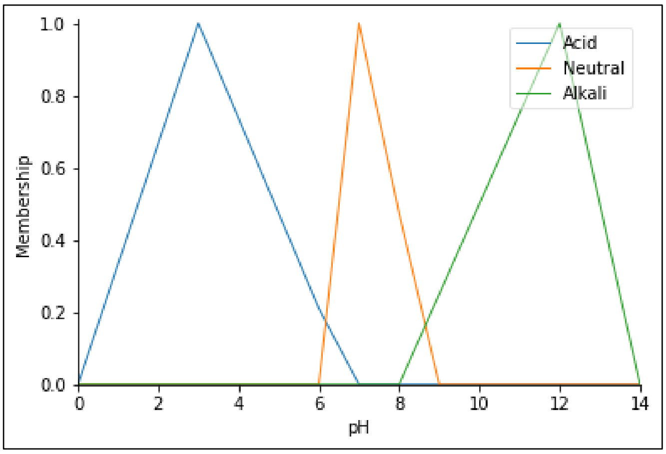

Figure 3.8: Membership Function of pH

The pH membership function, shown in Figure 3.8, is used to assess an element's level of membership or possibility of fitting into a given set of linguistic terms. "Acid," "neutral," and "alkaline" are three separate terminologies used to describe the pH levels. The term "acid" refers to the pH range of 0 to 4, which denotes a higher probability of acidity. The pH value for the neutral term, which ranges from 6 to 8, is closer to neutrality. Finally, the term "alkaline" refers to the pH range of 10 to 14, which denotes a higher likelihood of alkalinity. Fuzzy logic systems may efficiently analyse pH readings and make defensible conclusions based on the linguistic terms assigned to the data by employing this membership function.

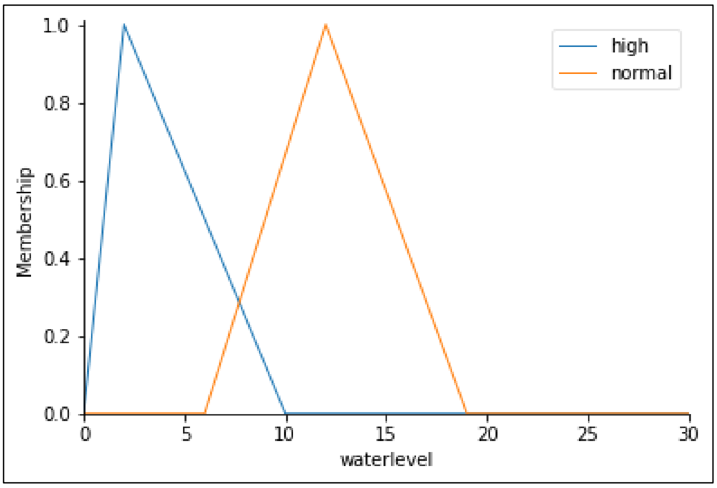

Figure 3.9: Membership Function of Water Level

The fuzzy logic system's membership function for water level consists of the linguistic terms "high" and "normal." The "high" notion denotes a water level that is between 0 and 10 cm above the water's surface, while the "normal" concept implies a level that is between 11 and 19 cm above the surface. The range of distances and their corresponding degrees of membership inside the fuzzy logic system are defined by these linguistic concepts. The fuzzy logic system can efficiently process and evaluate the water level data and make defensible decisions about how to operate the water pump in the aquarium by adding these membership functions.

Table 4. Fuzzy Logic Testing Results

Pengujian Ke.	Suhu	pH	System Testing Results	Fuzzy Rule	Results of Calculation Formulas
1.	25.19	5.91	Drained	Drained	Drained
2.	28.4	6.7	Not Drained	Not Drained	Not Drained
3.	25.25	11	Drained	Drained	Drained
4.	29.25	5.28	Drained	Drained	Drained
5.	31.78	9	Drained	Drained	Drained

Figure 3.10: Fuzzy Logic Testing Result

Fuzzy logic testing results are shown in figure 3.10. It has been determined from the outcomes of the five tests that the system's outputs comply with the pre-set fuzzy rules established during the design phase (Adin, N, 2020). The automatic drainage system was developed using these ambiguous principles as guidelines. The results of the algorithm also agree with hand calculations made using the appropriate formulas (Adin, N, 2020). This consistency shows that the fuzzy logic design and implementation are successful because the outputs produced are consistent with how the system is supposed to behave.

3.5 Dashboard Design

The dashboard design of a water quality system for an aquarium is an important component that offers aquarium owners an user-friendly interface for monitoring and analysing the important water quality indicators in their aquariums. It requires creating an understandable visual display that provides real-time information on water temperature, pH levels, water level concentrations, as well as other pertinent variables. The dashboard's design seeks to give customers a thorough picture of the aquarium's water quality, making it simple for them to understand the data and, if necessary, modify water parameters or start maintenance processes. The dashboard design improves user experience and facilitates efficient maintenance of the aquarium's water quality by making the data easily understandable and accessible.

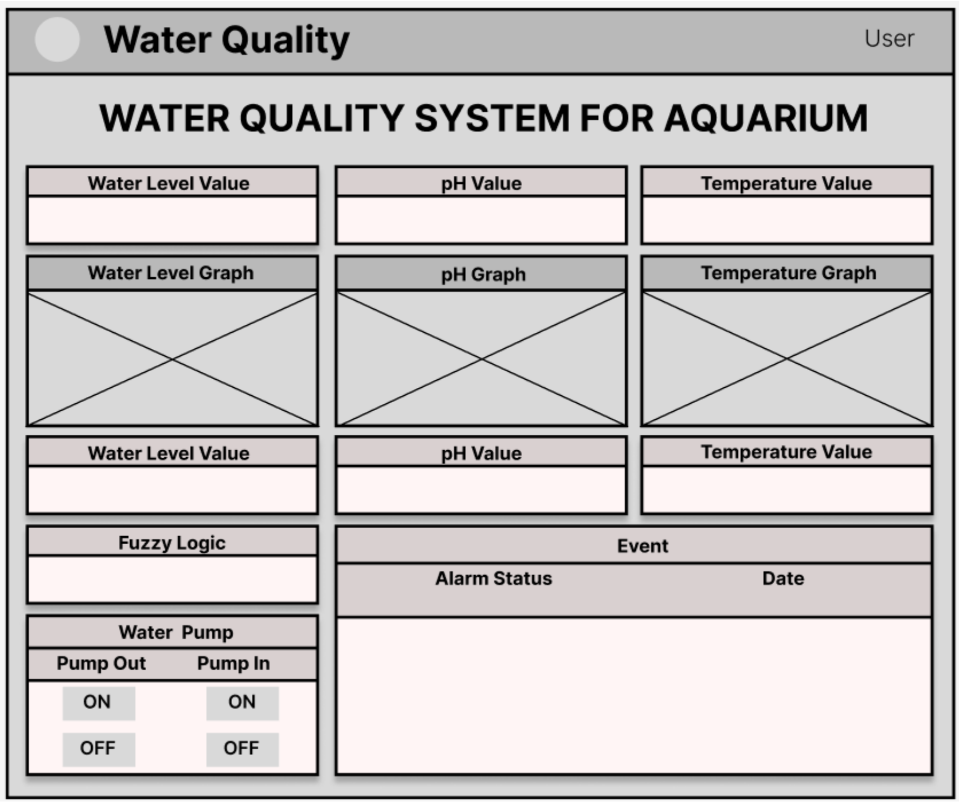

Figure 3.11: Water Quality System for Aquarium Dashboard Wireframe

The dashboard showcases key data values for the water quality system, including water temperature, water pH, and water level. Additionally, graphical representations such as graphs are provided to visualize the trends of temperature, pH, and water level over time. The dashboard also indicates the current status of the three data parameters, allowing users to easily monitor the conditions of the aquarium. Furthermore, the fuzzy logic status is displayed, providing insights into the decision-making process based on the fuzzy rules. The dashboard incorporates interactive buttons for controlling the water pump, enabling users to initiate pumping actions to either pump out or pump in the water as required. Additionally, an alarm status is included to promptly alert users to any critical issues or alarming conditions that may arise. This comprehensive dashboard interface offers a user-friendly and informative display for effective monitoring and management of the water quality system in the aquarium.

3.6 Analytic Feature Design

Fuzzy reasoning and inference techniques are incorporated into the analytical feature design of a water quality system for an aquarium with an emphasis on analysing the gathered data. Water quality measurements frequently involve ambiguous or inaccurate information, which fuzzy logic can handle. Membership functions and rule-based systems are used in the design to translate input data like pH, temperature, and water levels to fuzzy sets. In order to assess the general state of water quality, fuzzy inference rules are developed based on expert knowledge or empirical data.

The membership values for various linguistic variables are displayed along with the fuzzy system's current state in the fuzzy logic graph. Each linguistic term refers to a certain circumstance involving the pH, temperature, and water level of the aquarium. On the graph, the current values of these variables are displayed along with a correlation coefficient for each linguistic variable.

The connection between the input variables (pH, temperature, and water level) and the output variable (fuzzy status) are defined by the fuzzy rules. These guidelines specify how the system perceives and reacts to various input value combinations. Based on the current environmental conditions, the system can use fuzzy logic to make intelligent decisions and give suitable control actions.

Using a set of rules, the fuzzy logic system converts input variables into output variables. These regulations are intended to capture the know-how and experience of the aquarium setting. According to one guideline, the fuzzy status is "acidic and cold" if the pH is high and the temperature is low (Adin, N, 2020). These guidelines aid in evaluating the proper steps or modifications required to keep an aquarium environment that is balanced and healthy.

The system can handle the inherent uncertainties and ambiguity associated with water quality parameters by introducing fuzzy logic into it. In order to maintain the aquarium conditions within the appropriate range for the welfare of the aquatic organisms, this enables stronger decision-making and control.

The decision-making section is responsible for determining how fuzzy logic operates and using knowledge base to decide the implication function to form a rule (Husada, 2020). The pH: acid, neutral, alkali, temperature: cold, normal, hot and water level: high, normal.

Table 3. 2 Fuzzy Input Data

Input Variable	Conditions			Unit
pH	Acid	Neutral	Alkali	#
Temperature	Cold	Normal	Hot	℃
Water Level (Distance from water base)	High	Normal		cm

Table 3.3 Output Fuzzy Data

Output Variable	Condition		
Pump Action	Normal	Moderate	Polluted
	Do Nothing	Pump Out	

The Table 3.2, fuzzy input variables in the water quality system for the aquarium include pH, temperature, and water level (distance from the water base). The pH variable is represented by three linguistic conditions: acid, neutral, and alkali, which indicate the acidity or alkalinity level of the water. The temperature variable encompasses three linguistic conditions as well: cold, normal, and hot, reflecting the temperature range in degrees Celsius. The water level variable is categorized into two linguistic conditions: high and normal, corresponding to the distance in centimeters from the water base. These fuzzy input variables, along with their linguistic conditions, provide essential information for the fuzzy logic system to analyze and make informed decisions based on the membership functions assigned to each linguistic concept. By considering the fuzzy input variables of pH, temperature, and water level, the water quality system can effectively monitor and control the aquarium's conditions, enabling optimal management of water quality for the well-being of the aquatic environment.

The pump in the water quality system is represented by the output fuzzy data in Table 3.3, which displays the conditions and accompanying actions. "Pump Action," which is the output variable, is divided into three linguistic conditions: normal, intermediate, and polluted. The system determines that no action is necessary in the "Normal" situation, and the pump stays off. In the "Moderate" condition, the pump is triggered to take action to solve the observed water quality problem by pumping out. When the water quality is in the "Polluted" condition, the system detects the severity of the issue and starts pumping out steps to reduce the pollution. The water quality system can effectively regulate the water quality in the aquarium by using fuzzy logic to intelligently analyse the output conditions and make decisions regarding the activation or deactivation of the pump.

Below are the fuzzy rule that has been constructed for the system.

Fuzzy Rule:

1. IF pH acid, temperature cold, and water high, THEN pump out.

2. IF pH acid, temperature cold, and water normal, THEN pump out.

3. IF pH acid, temperature normal, and water high, THEN pump out.

4. IF pH acid, temperature normal, and water normal, THEN pump out.

5. IF pH acid, temperature hot, and water high, THEN pump out.
6. IF pH acid, temperature hot, and water normal, THEN pump out.
7. IF pH neutral, temperature cold, and water high, THEN pump out.
8. IF pH neutral, temperature cold, and water normal, THEN pump out.
9. IF pH neutral, temperature medium, and water high, THEN pump out.
10. IF pH neutral, temperature medium, and water normal, THEN do nothing.
11. IF pH neutral, temperature hot, and water high, THEN pump out.
12. IF pH neutral, temperature hot, and water normal, THEN pump out.
13. IF pH alkali, temperature cold, and water high, THEN pump out.
14. IF pH alkali, temperature cold, and water normal, THEN pump out.
15. IF pH alkali, temperature medium, and water high, THEN pump out.
16. IF pH alkali, temperature medium, and water normal, THEN pump out.
17. IF pH alkali, temperature hot, and water high, THEN pump out.
18. IF pH alkali, temperature hot, and water normal, THEN pump out.

3.7 Potential Use of Proposed Solution

There are various potential applications for the suggested aquarium water quality system. It makes it possible to continuously keep track of the conditions in the aquarium by enabling real-time monitoring of pH, temperature, and water level. It acts as an early warning system by informing users when parameters go outside of desired bounds thanks to built-in alarm mechanisms. By integrating actuators like pumps, the system can automate processes and provide prompt responses to maintain ideal conditions. It enables trend analysis and well-informed decision-making by storing data. Furthermore, a web-based dashboard enables remote access and gives customers the ability to monitor parameters, get alerts, and manage system operations. In conclusion, this approach promotes the health of the aquarium environment by improving monitoring, early detection, automation, data analysis, and remote accessibility.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, we present the findings of our study into the aquarium's water quality system and participate in a thorough analysis of them. This chapter is concerned with the results of the application of various parts, such as microcontrollers, sensors, actuators, and data processing systems. We use fuzzy logic to make decisions when we analyse the information gathered about water temperature, pH levels, and water level. The performance, accuracy, and efficacy of the system in preserving ideal water conditions for the aquarium are thoroughly examined in this chapter. We also consider how the findings might affect the management and monitoring of water quality. Through a comprehensive discussion, we evaluate the strengths, limitations, and potential areas for further improvement in the water quality system. The results and discussion presented in this chapter offer valuable insights into the overall performance and functionality of the system, contributing to the advancement of aquarium water quality control techniques.

4.2 Implementation

The implementation of the water quality system for the aquarium involved a series of steps to bring the system to life. This chapter provides an overview of the implementation process, detailing the hardware and software setup, sensor integration, connectivity configuration, and data management procedures. We discuss the selection and installation of the microcontrollers, such as the ESPDuino32 and Raspberry Pi 3B+, which served as the backbone of the system. Furthermore, we explore the integration of various sensors, including pH, temperature, and ultrasonic sensors, to gather essential water quality data. The chapter also delves into the configuration of the MQTT broker for seamless data transmission and the utilization of fuzzy logic for intelligent decision-making. We examine the challenges encountered during the implementation phase and the solutions adopted to overcome them. By presenting the implementation details, this chapter provides a comprehensive understanding of how the water quality system was brought to fruition, setting the stage for the subsequent chapters that delve into the results, analysis, and discussion of the system's performance.

4.2.1 Hardware Setup

Different parts can be assigned to the ESPDuino32 and Raspberry Pi 3B+ microcontrollers to build a hardware arrangement for an aquarium water quality system. The DS18B20 temperature sensor and an ultrasonic sensor can be used on a single ESPDuino32 board to measure the temperature and water level, respectively. The temperature and water level of the aquarium are continuously monitored by these sensors.

The pH E201-C (blue) sensor can be used on the other ESPDuino32 board just for pH level monitoring. The pH balance is continuously monitored by this sensor, which is essential for preserving an environment that is suitable for aquatic life.

The water quality system's numerous components can be managed using the Raspberry Pi 3B+. Pumps that control the aquarium's water quality can be controlled by attaching relays to the Raspberry Pi. Based on predefined criteria or user-defined rules, the Raspberry Pi analyses it, and activates the relays to turn on the pumps.

4.2.2 MQTT Broker

In order to gather information from sensors in the water quality system, the ESPDuino32 has previously been configured with a MQTT broker. Three different forms of information are successfully collected: pH level, water temperature, and water level. The pH sensor determines if the water is acidic or alkaline or neutral, the temperature sensor gives the water's current temperature, and the water level sensor shows how deep or high the water is in the aquarium. These data points are disseminated to the appropriate subjects on the MQTT broker as MQTT messages. The ESPDuino32 was configured as a MQTT client, subscribing to the pertinent topics, to further process and analyse this data.

4.2.3 MySQL

A MySQL database called "waterquality" can be used to hold the sensor data for the water quality system, which includes information on temperature, pH level, and water level. The database contains four tables called temperature, phwater, waterlevel, and alarmtelegram in order to efficiently organise the data. The 'temperature' table is used to record temperature readings, 'phwater' saves pH level information, and 'waterlevel' stores water level observations. Additionally, a table called "alarmtelegram" is constructed to manage alert notifications sent via Telegram if the pH level or water's temperature go from being moderately acidic to overly alkaline.

An alarm trigger is activated when the pH level exceeds predetermined criteria signifying acidity or alkalinity. The technology notifies the user of the aquarium's unfavourable condition by sending an alarm notification to a chosen Telegram account. This function guarantees that any water quality issues may be addressed quickly, assisting in the maintenance of an aquarium with an appropriate habitat for aquatic life.

4.2.4 AI Server

The AI server integrates with a web server to retrieve input data, serving a critical part in the water quality system. Fuzzy rules are created using this input data as their starting point, and they are then utilised to identify the associated output data. The fuzzy rules are intended to establish the links between the input variables and the output conditions as well as to reflect the complexity and variability of the water quality metrics. The output data in this instance is divided into three categories: normal, moderate, and polluted. The AI server uses the incoming data to evaluate the degrees of membership for each condition and make precise decisions by using fuzzy logic principles. As a result, the system can offer insightful information and support for making decisions considering the observed water quality conditions. The AI server's capacity for input data analysis, fuzzy rule application, and relevant output data generation helps with efficient water quality monitoring and management in the aquarium, maintaining a healthy and prosperous environment for aquatic life.

4.3 Result

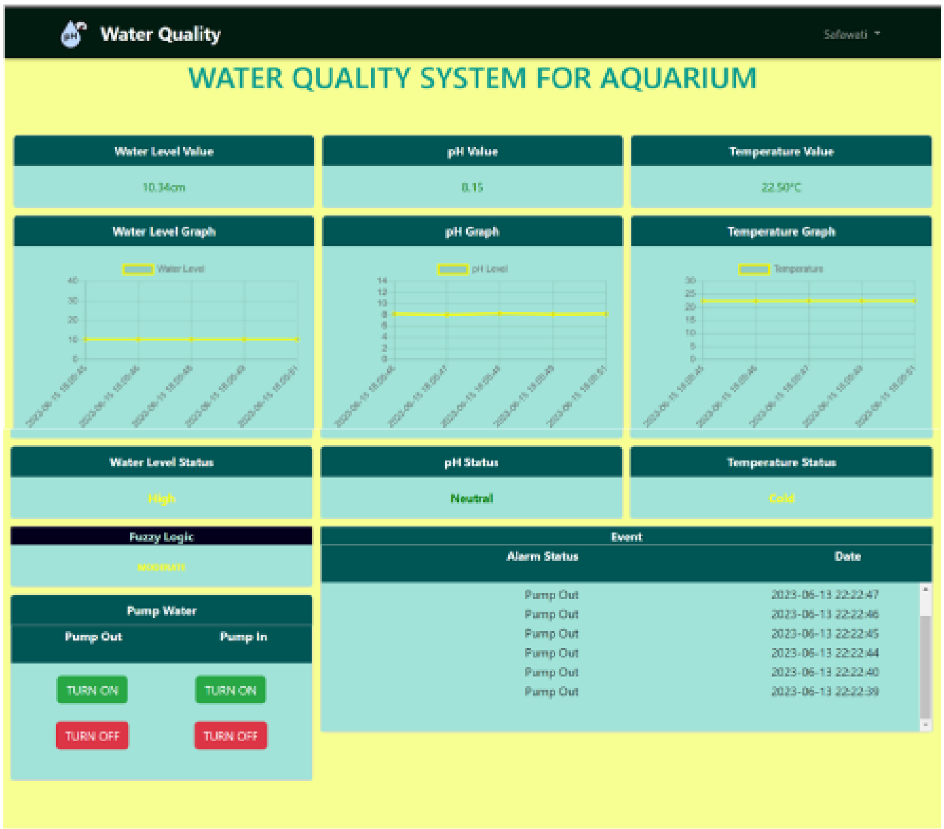

Figure 4.12: Dashboard of IoT Based Water Quality for Control Small-Scale Aquarium with Fuzzy Logic

The implemented dashboard for the water quality system has yielded significant results and provided a platform for valuable discussions. The integration of user sign-up and login functionalities ensures a secure and personalized experience for users. Upon logging in, the dashboard presents essential information related to the water quality parameters, including pH, temperature, and water level.

The dashboard efficiently shows the pH, temperature, and water level in real-time, allowing users to keep track of the aquarium's present conditions. Additionally, these characteristics are shown in graphical form, enabling users to spot trends and patterns over time. Understanding the historical data and spotting any changes or anomalies in the water quality are made easier thanks to this graphic representation.

The dashboard also prominently displays the fuzzy logic system's status. The system analyses the gathered data and generates intelligent decision-making based on established rules by utilising fuzzy logic techniques. The fuzzy logic status enables users to figure out the overall health of the aquatic environment by revealing whether the water quality is normal, moderate, or polluted.

The dashboard's display of the alert state is another noteworthy feature. This feature notifies users of any urgent circumstances or unusual conditions the system detects. The alarm status makes sure that users are swiftly alerted to any problems that require for immediate attention and intervention, protecting the aquarium's residents in the process.

Additionally, the dashboard has controls that can be used to regulate the water pump, giving customers the option to do things like pump water in or out. Users may easily modify and maintain the desired water conditions thanks to this feature, which enables convenient control over the water level in the aquarium.

Overall, the dashboard's results and analysis show how useful it is for giving a thorough overview of the variables affecting water quality, fuzzy logic status, alarm notifications, and water pump control options. The functionality of data display, graphical representation, and control buttons when combined results in a better user experience and makes it possible to monitor and manage the aquarium environment effectively. The dashboard is an effective instrument for ensuring the wellbeing and ideal circumstances of the aquatic ecosystem.

4.4 Fuzzy Result

Input variables are precisely defined. With a range of 0 to 14, the pH variable indicates how acidic or alkaline the water is. The three fuzzy settings are "Acid," "Neutral," and "Alkali." Low pH values, ranging from 0 to 3, and a peak membership value that is centred at 6.8 define the "Acid" fuzzy set. The 'Neutral' fuzzy set denotes a pH level that is neutral, with a range of 6 to 7 and a peak of 8.9. The 'Alkali' fuzzy set refers to high alkalinity, with a range of 8 to 12 and a peak of 14. It showns at figure 4.13.

Figure 4.14, with a range of 0 to 40 degrees Celsius, the temperature variable reflects the water's temperature. It is separated into the "Cold," "Normal," and "Hot" fuzzy settings. The 'Cold' fuzzy set reflects cooler temperatures, with a peak of 24 degrees Celsius and a range of 0 to 10 degrees Celsius. The peak temperature of the 'Normal' fuzzy set, which ranges from 23 to 27 degrees Celsius, indicates ordinary or mild temperatures. The 'Hot' fuzzy set denotes hotter temperatures, with a range of 28 to 32 degrees Celsius and a peak temperature of 40.

The range of the water level variable, which represents the separation between the water level and the water base, is 0 to 30 cm. As shown in figure 4.15, 'High' and 'Normal' are the two fuzzy sets that make up this spectrum. The 'High' fuzzy set, with a range of 0 to 5 cm and a peak of 2, symbolises a water level near the water base. The 4 to 9 cm range covered by the 'Normal' fuzzy set denotes a moderate water level.

Moving on to the output variable, the condition variable represents the overall condition of the water based on the inputs. It has a range from 0 to 100, divided into three fuzzy sets: 'Normal', 'Moderate', and 'Polluted'. The 'Normal' fuzzy set represents a good water condition, ranging from 0 to 67.5, with the peak at 33.75. The 'Moderate' fuzzy set indicates a moderate or fair condition, ranging from 62.5 to 80, with the peak at 71.25. The 'Polluted' fuzzy set represents a poor or polluted condition, ranging from 75 to 100, with the peak at 87.5. The membership of condition shown as figure 4.16.

The link between the inputs and the output is specified by the 18 rules that make up the rule base. The conditions under which a particular output value is allocated based on the fuzzy sets of pH, temperature, and water level are specified in each rule. For example, rule 1 indicates that the condition is "Polluted" if the pH is "Acid," the temperature is "Cold," and the water level is "High." To find the suitable output condition, the rule base integrates numerous input conditions using logical operators like "AND" and "OR."

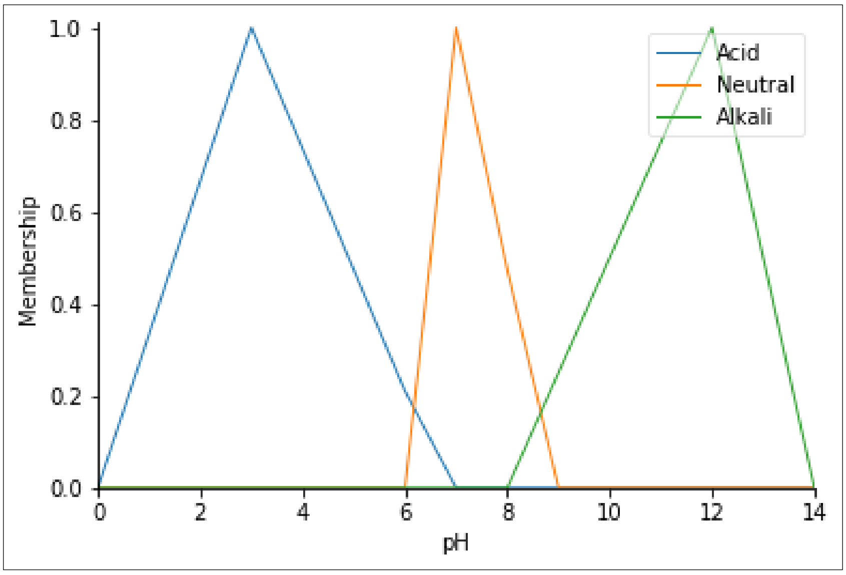

Figure 4.13: Membership Fuzzy of pH

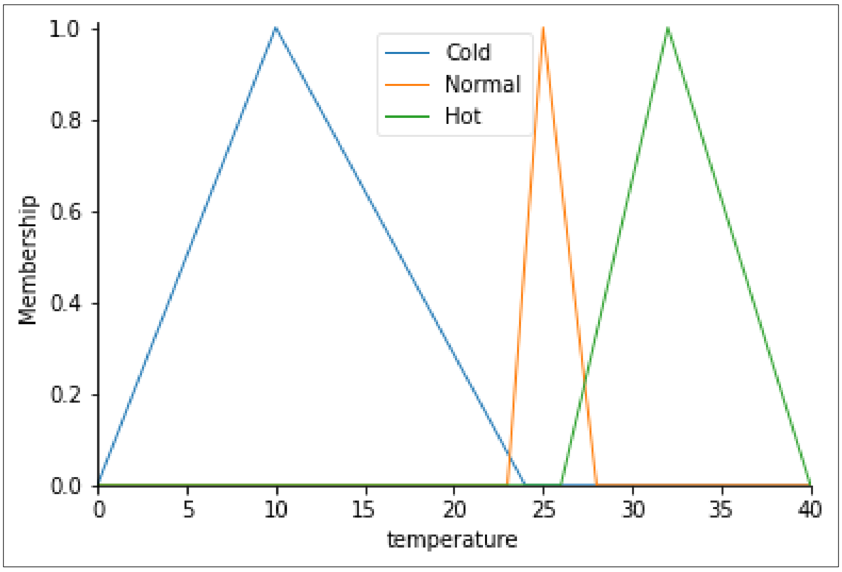

Figure 4.14: Membership Fuzzy of Temperature

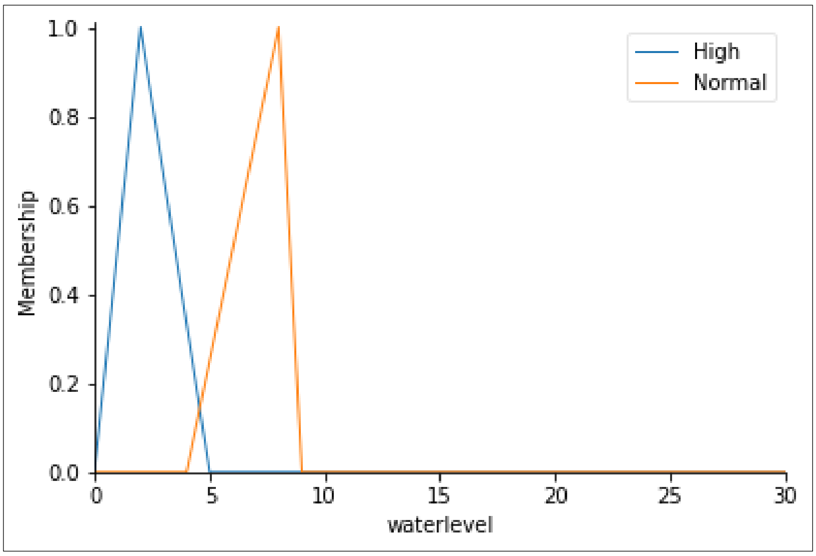

Figure 4.15: Membership Fuzzy of Water Level

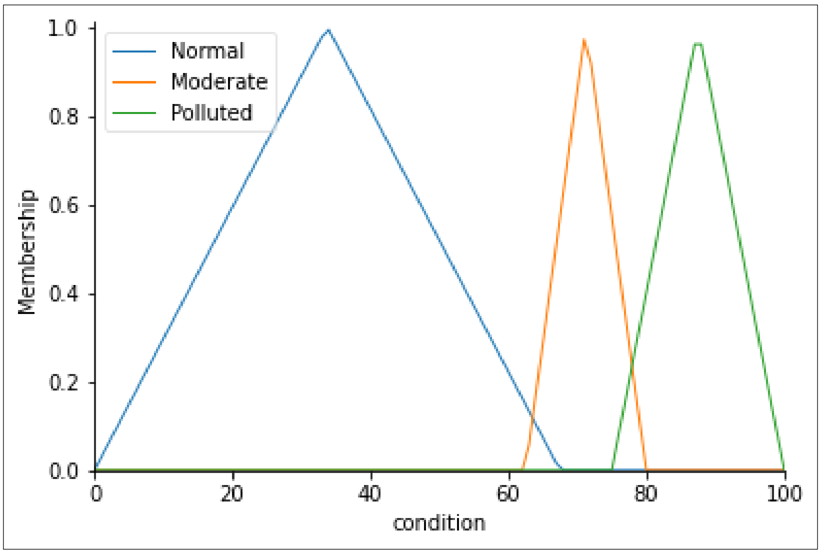

Figure 4.16: Membership Fuzzy of Condition

CHAPTER 5

CONCLUSION

5.1 Introduction

In this final chapter, we present the conclusion of our study on the water quality system for the aquarium. Throughout the preceding chapters, we have explored the implementation, results, and discussion of the system, delving into the hardware setup, sensor integration, data management, fuzzy logic application, and AI server configuration.

5.2 Conclusion

In conclusion, the water quality system developed for the aquarium has successfully addressed the challenges associated with monitoring and maintaining optimal conditions for aquatic life. Through the integration of microcontrollers, sensors, data management techniques, fuzzy logic, and an AI server, a comprehensive solution has been achieved that provides real-time monitoring, intelligent decision-making, and efficient control of water quality parameters.

The project has demonstrated the effectiveness of the implemented system in accurately measuring and analyzing key parameters such as water temperature, pH levels, and water level. The integration of fuzzy logic and fuzzy rules has enabled informed decisions regarding water quality and appropriate actions to be taken as needed. The AI server has enhanced the system's capabilities, enabling advanced data processing and intelligent prediction.

Throughout the project, various challenges related to hardware setup, sensor integration, connectivity configuration, and data management were successfully addressed. The system has been optimized to ensure reliable and accurate measurements, as well as seamless communication between components. The inclusion of a user-friendly dashboard provides an intuitive interface for monitoring water quality and controlling system operations.

The results obtained from the project demonstrate the system's effectiveness in maintaining a healthy and thriving environment for aquatic life in the aquarium. Continuous monitoring and management of water temperature, pH levels, and water level help prevent adverse conditions that may harm the well-being of the inhabitants. The system's ability to provide timely alerts and notifications through channels like the Telegram app ensures prompt responses and interventions in case of abnormalities.

Looking ahead, there are opportunities for further improvement and expansion of the system. This may involve incorporating additional sensors to measure other water quality parameters, integrating automated feeding mechanisms, and exploring advanced analytics techniques for more sophisticated decision-making. The application of machine learning algorithms could also enable the system to adapt and optimize its operations based on historical data and patterns.

In summary, the water quality system developed for the aquarium serves as a valuable tool for aquarium enthusiasts, researchers, and professionals involved in maintaining aquatic environments. By providing accurate and real-time data, intelligent decision-making capabilities, and efficient control mechanisms, the system contributes to the well-being and longevity of aquatic life, ensuring an enjoyable and thriving aquarium experience.

5.3 Research Constraints

There are various restrictions on the amount of research that can be done on IoT-based fuzzy logic water quality control in tiny aquariums. These include physical constraints like space, electricity, and computing capacity, which might affect the choice and integration of devices. It is extremely difficult to ensure precise and trustworthy pH, temperature, and water level sensors. The processing speed and network connectivity of real-time data processing may be constrained. It takes a lot of research to create acceptable fuzzy logic rules that appropriately depict water quality circumstances. Additional factors to take into account include scalability, cost-effectiveness, and building a user-friendly interface while keeping in mind the limitations of small-scale aquariums. To overcome these limitations, careful experimentation and optimisation are needed to create a water quality control system that is efficient and simple to use.

5.4 Project Limitations

There are some limits to the IoT-based fuzzy logic water quality control project for small aquariums that should be acknowledged. First off, the project's findings and results might be unique to small-scale aquariums and might not simply apply to other aquatic ecosystems or bigger aquarium systems. Second, the reliability of the system may be affected by the precision and accuracy of the pH, temperature, and water level sensors. It's crucial to take into account the sensor technology and calibration restrictions. Thirdly, it can be difficult to create fuzzy logic rules that appropriately depict water quality circumstances, and it's possible that the chosen linguistic variables and rule sets fall short of capturing the whole complexity of the dynamics of the aquarium. It might be technically difficult to integrate and maintain IoT devices, data processing algorithms, and network connectivity. For better user experience and uptake, it's imperative to provide a user-friendly interface and transparent data visualisation. The implementation of the system should take environmental variability and adherence to laws governing the control of aquarium water quality into account.

5.5 Future Work

IoT Based Water Quality Control for Smale-Scale Aquarium with Fuzzy Logic creates opportunities for future development and improvements. The incorporation of machine learning methods to increase the system's accuracy and predictive power is one direction for future growth. The system may learn and adapt to changing water conditions by utilising past data and cutting-edge analytics approaches, enabling more precise management and proactive maintenance of water quality. Incorporating mobile applications or cloud-based platforms with remote monitoring and control capabilities would also give aquarium owners easy access to real-time information and control options from anywhere. The system's capabilities could also be improved by investigating the use of new sensor technologies, such as optical sensors for measuring water quality indicators or cutting-edge imaging methods for monitoring fish health. The system could also be adjusted and optimised for different configurations and species by performing extensive field experiments and gathering data from varied aquarium conditions, ensuring its effectiveness and adaptability across a variety of small-scale aquariums.

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