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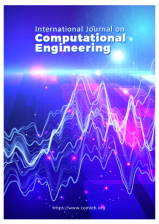

FiSH: Fish Smart Habitat – An IoT-based Smart Aquarium Monitoring System

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Abstract*—Maintaining a healthy aquarium environment for pet fish is essential due to the critical influence of factors like pH, temperature, and oxygen levels. Sudden pH change can compromise fish immunity and escalate disease susceptibility. Overfeeding poses stress and health risks. Effective water quality management is pivotal, improving fish well-being and reducing the necessity for chemical interventions. Thus, this project endeavours to craft an aquarium integrated with a mobile application, streamlining the user's responsibility of nurturing a healthy aquatic habitat for their pet fish through employment of the Mobile Application Development Lifecycle (MADLC). The system employs an ATmega2560 board, an analog pH sensor, and a temperature sensor to detect pH levels and monitor water temperature. The project's core objective is to identify the system requirements, design and develop the FISH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring System Mobile Application. This venture holds significance in its endeavour to enhance fish health by leveraging IoT technology to oversee and regulate the habitat. The application extends remote fish feeding and provides status updates on water conditions, gauging pH suitability based on the fish species within the aquarium. Test users attested to the product's efficacy, yielding an average System Usability Scale (SUS) score of 86.25. This project boasts a promising potential to positively transform fish care methodologies. In conclusion, the FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring System mobile application not only simplifies aquarium upkeep but also curtails costs and propels fish growth. This initiative contributes to a sustainable and health-conscious approach to aquarium management. Moving forward, the project will enhance the aquarium interface by incorporating supplementary hardware, including a controllable LED.

***Keywords*—Healthy aquarium environment; analog pH sensor; system usability scale; monitoring system; internet of thing.**

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INTRODUCTION

People tend to have aquariums in their homes to keep their pet fishes, today. It has been estimated that up to 3.9 million homes in the United Kingdom have fish as their pet animal. There are between 117 million and 134 million fish kept in the 26.3 million UK households, of which it is estimated that 9% keep indoor fish and 6% keep outdoor fish [1]. Assuming that there is no overlap between indoor and outdoor fish keepers, it is estimated that there are around 3.9 million UK households that own fish. Despite being common trends, petting a fish can be difficult because maintaining an aquarium is a challenging task [2].

There are many factors that need to be taken into account when it comes to keeping the fish alive which is an ideal condition. This comes with the complexity in keeping a healthy pet fish in the aquarium. Fish require the utmost care because their environment is completely different from land animals, so they need specific conditions like temperature range, pH, suitable oxygen and CO2 levels.

Despite the challenges, the allure of owning an aquarium and the joy of observing and caring for fish attract many enthusiasts. These aquatic setups not only serve as beautiful decorative elements but also offer a sense of tranquility and relaxation. However, to ensure the well-being of the fish and create a healthy habitat, responsible and informed care practices are crucial.

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because their environment is completely different from land animals, so they need specific conditions like temperature range, pH, suitable oxygen and CO2 levels.

Since pH is such an important factor for fish, sudden changes in pH can be very harmful to them. Hence, the recommended pH range for is from 6.5 to 9.0 [3]. Although pH outside of the optimum range may not kill fish, it is a constant stressor that can lower the immune system, making fish more susceptible to diseases and for that, the pH of the tank water should be tested once a week for optimum fish health. A good water quality management approach will decrease fish illness issues, encourage development, and limit the need for chemical treatments [4].

In addition, fish feeding can be a challenging task for fish keepers when they are away from the fish tanks or when they are traveling. This has led to people not being able to keep their homes clean, especially for those with fish aquariums. They might be unable to feed their fish on time or clean the aquarium frequently. If a fish tank is not cleaned frequently, waste products from the fishes would accumulate in the water, thus, making the water cloudy [5]

Overfeeding is one common mistake made by fish owners before traveling, as its produced significant stress and immunosuppression, perhaps increasing sensitivity to infectious illnesses [6] and uneaten food can pollute the water. Aquarium inhabitants that live in water are easily affected by changes in the aquarium temperature, feeding, and lighting. As a result, residual feed is polluting the aquarium and disturbing the pH stability of the water in aquarium [7].

A. Literature Review

Aquariums have been a popular form of home and office decoration for decades and have been found to have a number of benefits for the people who interact with them. Having an aquarium in the home or office can lead to reduced stress levels, improved mood, and increased productivity. One study conducted by [8] showed that having an aquarium in the clinic led to a significant reduction in self-reported stress levels among patient, as well as reduce anxiety while in waiting area . Another study conducted by [9] found that having an aquarium in the workplace led to positive productivity and create good among employees. Aquariums can also have a positive impact on mental health. pH is a measure of the acidity or basicity of water. It is an important water quality parameter in aquariums as it can affect the health and well-being of the fish and other aquatic species. The pH of aquarium water should be within a certain range, typically between 6.5 and 9.0, to provide a suitable environment for the fish and other aquatic species [3]. Although pH outside of the optimum range may not kill fish, it is a constant stressor that can lower the immune system, making fish more susceptible to diseases and for that, the pH of the tank water should be tested once a week for optimum fish health. A good water quality management approach will decrease fish illness issues, encourage development, and limit the need for chemical treatments [4].

Overfeeding is an issue in both aquaculture and home aquariums. It’s not only waste food and money, and it can decrease water quality, causing stress and the spread of secondary illnesses or parasites [10] and can have negative impacts on the health and well-being of the fish as well as the overall water quality. Overfeeding is one common mistake made by fish owners before traveling, as its produced significant stress and immunosuppression, perhaps increasing sensitivity to infectious illnesses [6] and uneaten food can pollute the water. Aquarium inhabitants that live in water are easily affected by changes in the aquarium temperature, feeding, and lighting. As a result, residual feed is polluting the aquarium and disturbing the pH stability of the water in aquarium [7]. To prevent overfeeding fish, it is important to monitor the amount of food that is being fed, and to adjust the feeding in specific time is necessary. It is also important to ensure that the fish are consuming all the food that is being fed to them, and to remove any uneaten food from the aquarium or aquaculture system. The Internet of Things (IoT) refers to the interconnectedness of physical devices and objects through the internet, allowing them to collect and share data [11]. IoT has the potential to revolutionize various industries and domains, such as healthcare, transportation, and manufacturing. The concept of Internet of Things (IoT) can be traced back to the early days of computer networking in the 1970s, when connected devices were first used to monitor and control various industrial processes. The term "Internet of Things" was coined in 1999 by Kevin Ashton, a British technology pioneer, who used it to describe the growing network of connected objects and sensors that were beginning to emerge. In the early 2000s, advancements in wireless communication and sensor technologies, coupled with the increasing availability of low-cost computing power, led to the development of more sophisticated IoT systems. These systems were initially used in industrial and commercial applications, such as supply chain management and building automation.

A study by [12], in ‘IoT Based Automatic Aquarium Monitoring System for Freshwater Fish’, stated, a monitoring for an automated fish tank is not a novel concept. The machine enables the user to instantaneously control the pH, temperature, turbidity, water level, and fish feeding. Nevertheless, manually checking the circumstances of an aquarium will be inconvenient. It takes time and requires dedication. In this case, an Internet of Things (IoT)-connected system is suggested to control and monitor the entire aquarium maintenance via electronics and sensors that constantly interact and transmit real-time status to the user's smartphone. The advanced system will monitor physiological changes inside the water and preserve it at optimal circumstances, with the system deciding on the necessary changes automatically. The aquarium would then perform all operations automatically, including temperature, pH, turbidity, feeding, and water level control. It will reduce the amount of manual labour required for aquarium management. Industry 4.0, also known as the Fourth Industrial Revolution, refers to the integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics into manufacturing and industrial processes [13]. This integration is expected to lead to significant improvements in efficiency, productivity, and flexibility. One study by [14] found that Industry 4.0 technologies can help manufacturers to achieve higher levels of automation, reduce human error, and improve decision-making. Another study by [15] found that Industry 4.0 technologies can help to optimize supply chain management, increase production speed and

quality, and reduce costs. Industry 4.0 is also expected to drive innovation, as new technologies and data-driven insights can lead to the development of new products and services [16]. Furthermore, Industry 4.0 is expected to have a significant impact on the workforce, as advanced technologies such as AI and robotics are expected to automate many tasks that are currently performed by humans [17]. 'Smart Aquarium' restate that Smart Aquarium, also known as "the home automation for aquatic animals," is a concept that provides aquatic animals with an artificial setting that they require for survival [18]. IoT technology is widely used in everyday life. IoT devices have been used to develop innovative residences, smart cities, and a variety of supporting applications. IoT can be employed in the pastime of fish keeping. Many people keep fish as pets at home these days. The fish were fed manually once a day. The difficulties encountered include quality of water, feeding the fish, controlling the temperature, and manually checking the circumstances of an aquarium. As a result, it is critical to tightly control the physical parameters and improve the water quality. As a result, this project envisions a system equipped with sensors that can function in real-time. It monitors the temperature of the water, detects the pH level of the water, and performs water renewal operations. An IoT-based system is used to track and deliver the aquarium's status to the person's mobile application. Thus, smart aquarium control has been implemented, lessening the conventional effort required for aquarium maintenance.

MATERIAL AND METHOD

There are many types of methodologies when creating the application or software but each of them have a different approach in the development process. The developers need to choose which methodology they want to apply in their project based on the project requirements. Mobile Application Development Lifecycle (MADLC) is one of the existing methodologies and it can be categorized as of the latest methodology.

According to [19], Mobile Application Development Lifecycle (MADLC) has seven phases which are identification phase, design phase, development phase, prototyping phase, testing phase, deployment phase and maintenance phase. This lifecycle is often used by developers that want to develop mobile applications. Mobile Application Development Lifecycle (MADLC) is a lifecycle that helps developers in planning the workflow of their project from the start of the project until the project has been developed.

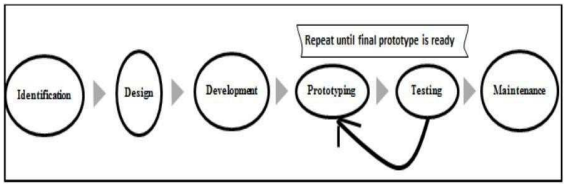


Fig. 1 Mobile Application Development Lifecycle (MADLC) Methodology Phase [19]

A methodology should be used and followed by a developer in order to produce a good system. Mobile Application Development Lifecycle (MADLC) includes the following phases: identification phase, design phase, development phase, prototyping phase, testing phase, deployment phase and maintenance phase. Figure 1 shows Mobile Application Development Lifecycle (MADLC) phase.

This methodology has seven steps, but for this project, only five will be used: the identification phase, the design phase, the development phase, the prototyping phase, and the testing phase.

A. *Identification Phase*

To create a good system, a developer should utilise and follow a methodology. The steps of the Mobile Application Development Lifecycle (MADLC) are as follows: identification, design, development, prototyping, testing, deployment, and maintenance. The first phase of the Mobile Application Development Lifecycle (MADLC) research methodology model is identification. It is a phase that combines the planning and analysis phases. During this phase, the developer must determine who the users are, what type of application the developer wishes to create, and the tools required to create the application. Effective project planning is critical to ensuring that the project runs smoothly, determining project success, and obtaining the best results. As a result, proper project planning is essential; otherwise, developers would be unable to plan the project adequately, resulting in failure projects. The important steps that will be carried out during the requirement planning phase are to determine the user requirements, problem statement, objective, project scope, and the project's significance. The major objective of this project is to apply Internet of Things (IoT) technologies to establish user needs for FISH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems. A large amount of research from journals, papers, conference proceedings, and books has been studied in order to acquire a better knowledge of project-related problems.

TABLE I
SUMMARY OF IDENTIFICATION PHASE AND ITS ACTIVITIES

Phase	Activity	Tools/Methods/ Techniques	Deliverable
Identification	Identify problem statement, objective, project scope and project significance	• Literature review • Tools: Google Scholars, journals and articles	• Problem statement, objective, project scope and project significance
	Identify existing application	•Literature review •Tools: Google Scholars, journals and articles	•Comparison of similar applications
	Identify system requirements	•Literature review •Google Scholars, journals and articles	•Systems requirements •Functional & Non-Functional Requirement. •IT Infrastructure Component
	Identify hardware and software	•Review existing application.	•List of hardware and software
	Plan the project execution schedule	•Microsoft Project	•Gantt chart

The user interface (UI) information is necessary for creating the application's interface. The current application is analysed in this phase to find the features and designs required to meet the user needs specifications. The functionality, design interface, and accessibility of similar applications will be compared. The comparison of similar applications will assist developers in creating a great application. The project schedule is developed as a timeline of when the project started and when it is expected to complete. It is an estimated project timeline, and the developer will work to meet the deadline based on the Gantt chart created with Microsoft Project. The identification phase and associated activities are summarised in Table 1. During this phase, actions will be carried out to collect data for user needs. It also demonstrates that the deliverable for requirement planning, which was the primary goal of this project, has been met.

The specific hardware that will be utilised to build the project is shown in Table 2, and the specific software that will be used in the creation of FiSH – Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems is shown in Table 3.

TABLE II
HARDWARE SPECIFICATION

No	Hardware	Specification
1	Laptop	•Asus •Intel 11th Gen Core i5-11400H •24 GB RAM •2.7 GHz •64-bit Operating System
2	Mobile phone	•Realme 5i •6.52-inch screen •720 x 1600 pixels at 269 ppi •4 GB RAM

TABLE III
SOFTWARE SPECIFICATION

No	Software	Specification
1	Android Studio	Integrated Development Environment (IDE)
2	Arduino IDE	Integrated Development Environment (IDE)

B. Design Phase

Using the information gathered during the requirement planning, the developer must develop a Use Case Diagram, Flowchart, circuit diagram, and database system during the design process. Use Case Diagrams, Flowchart and prototyping are created with Draw.io, whereas Circuit.io is used to design the circuit diagram. As a result, the deliverables for this phase include a Use Case Diagram, a Flowchart, a Low-fidelity prototype and a Circuit Diagram. Table 4 summarises the design phase and related actions.

TABLE IV
SUMMARY OF DESIGN PHASE AND ITS ACTIVITIES

Phase	Activity	Tools/Methods/ Techniques	Deliverable
Design	Design low-fidelity User Interfaces for FISH mobile application	• Moqups	• Low-fidelity UI & storyboard
	Design Use Case Diagram, Flowchart and Sequence Diagram	• Canva • Draw.io	• Use Case Diagram • Flowchart • Sequence Diagram
	Design circuit diagram for FiSH: Fish Smart Habitat IoT Systems	• Circuito.io	• Circuit diagram for FiSH: Fish Smart Habitat IoT Systems

C. Development Phase

During the development phase, the software is used to design the User Interface (UI) and the database. To visualise and describe the proposed application, a user interface (UI) was created in Android Studio. The database is meant to hold data and information throughout this time. The development phase and related activities are summarised in Table 5.

TABLE V
SUMMARY OF DEVELOPMENT PHASE AND ITS ACTIVITIES

Phase	Activity	Tools/Methods/ Techniques	Deliverable
Development	Develop authentication database	• Firebase	• Authentication Database
	Develop datastream connection	• Blynk Cloud	• Datastream connection
	Develop user interface	• Android Studio	• User interface
	Develop circuit for FiSH: Fish Smart Habitat IoT Systems	• Arduino IDE	• Configure Arduino MEGA, servo motor, temperature sensor and pH sensor

D. Prototyping Phase

During the prototyping phase, the user interface is transformed into a functional functioning prototype. Developers can make any new modifications during this phase. The prototype phase and associated activities are summarised in Table 6.

TABLE VI
SUMMARY OF PROTOTYPING PHASE AND ITS ACTIVITIES

Phase	Activity	Tools/Methods/ Techniques	Deliverable
Prototyping	Develop high-fidelity prototypes of the FiSH mobile application.	• Android Studio • Arduino IDE	• Functional high-fidelity prototype of the FiSH mobile application is produced

E. Testing Phase

User testing will be performed during the testing process to ensure that the application functions properly. It is critical to determine whether or not users understand how to utilise the application. During the testing phase, users will be given a set

of tasks to complete and to ensure that the application works effectively, and the developer will need to gather feedback from the users so that the application may be improved. Table 7 shows the task activities that users must complete during user testing.

TABLE VII
SYSTEM USABILITY SCALE (SUS) QUESTIONNAIRE [20]

No	SUS Question	Strong Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
1	I think that I would like to use this FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application frequently.					
2	I found the FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application unnecessarily complex.					
3	I thought the FiSH: Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application was easy to use.					
4	I think that I would need the support of a technical person to use this FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application quickly.					
5	I found the various functions in this FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile applications were well integrated.					
6	I thought there was too much inconsistency in this FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application.					
7	I would imagine that most people would learn to use this FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application very quickly.					
8	I found the FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application very cumbersome to use.					
9	I felt very confident using the FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application.					
10	I needed to learn a lot of things before I could get going with this FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application.					

TABLE VIII
TASK ACTIVITY FOR USER DURING USER TESTING

No. of task	Task Activity
Task 1	Connect with smart aquarium
Task 2	Get information about current water pH level
Task 3	Get information about current water temperature
Task 4	Feeding fish in real time

After the completion of the task, the users will be interviewed to obtain feedback based on the task activities listed in Table 8. The developer will use feedback to enhance the application in the future. As a result, the application may be updated by incorporating user comments. Table 9 summarises the testing phase and related activities.

TABLE IX
SUMMARY OF TESTING PHASE AND ITS ACTIVITIES

Phase	Activity	Tools/Methods/ Techniques	Deliverable
Testing	Perform usability testing	• Task activities • System Usability Scale (SUS) questionnaire	Testing result

Before the testing session, users were given the .apk file, which they used to download the FiSH – Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application and attempt the tasks listed. After completing the tasks, users must complete a Google Form to ask a series of questions about the mobile application as in Table 7.

According to the responses given in the Google Form by the eight users, the mobile application met their expectations. All the features created for this mobile application work properly. The UI, including the design interface and color choices for the mobile application, is well-liked by all users. Furthermore, they discovered that all the buttons used aided them in navigating through this application more quickly and easily. Above all, users were impressed that the features developed would aid in the creation of a healthy aquarium environment for pet fish. Furthermore, all users find this application to be very simple but very effective, as they can quickly make decisions based on the data. Last but not least, two users suggested that this application be available on the iOS platform and that the scope of this application includes adding additional hardware to the board, such as LEDs (Refer Table 10).

TABLE X
SUS SCORE RESULT

	User 1	User 2	User 3	User 4	User 5	User 6	User 7	
Question 1	4	4	5	4	5	4	5	4
Question 2	2	2	1	2	1	1	2	1
Question 3	5	4	5	5	5	4	5	4
Question 4	1	2	1	2	1	1	2	1
Question 5	4	4	5	3	5	4	5	4
Question 6	1	2	1	1	1	1	2	1
Question 7	5	4	5	4	5	4	5	4
Question 8	1	2	1	2	1	1	2	1
Question 9	5	5	5	5	5	4	5	4
Question 10	1	2	1	1	1	1	2	1
x = (Sum of Odd) -5	18	16	20	16	20	15	20	
y = 25 – (Sum ofEven)	19	15	20	17	20	20	15	
SUS Score [(x+y)*2.5]	92.5	77.5	100	82.5	100	87.5	87.5	

The data collected in the Google Form was used to calculate each the applicant's system usability score (SUS). The third and fifth users have the highest SUS score of 100. The seventh participant has the lowest SUS score of 62.5. This mobile app's SUS scores averaged 86.25, which, as shown in Figure 2, places it well inside the "excellent" category.

Fig. 2 System Usability Score [20]

RESULT AND DISCUSSION

The results and discussion of FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring System Mobile Application are the focus of this section. All three goals are met, and the method and process used are discussed. This section also includes analysis data, information, and design development to ensure that the project's objectives are met. This section also discusses the requirement analysis, design prototype, use case diagram, and screenshots of FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application.

A. Identification of Data and System Requirements

For FiSH: Fish Smart Habitat – An IoT Based Smart Aquarium Monitoring Systems to be developed, it first needed to identify and gather the functional and non-functional requirements for the application features. The requirements needed to develop FiSH: Fish Smart Habitat – An IoT Based Smart Aquarium Monitoring Systems Mobile Application have been gathered through an extensive review from the literature review.

1) System Requirements

System requirements described the functional and non-functional requirements of the system that will be implemented in the FiSH: Fish Smart Habitat – An IoT Based Smart Aquarium Monitoring Systems Mobile Application. The literature review that has been discussed helps in identifying the functional and non-functional requirements that are needed in developing this project. Therefore, the functionalities of the FiSH: Fish Smart Habitat – An IoT Based Smart Aquarium Monitoring Systems mobile application to achieve specific goals are listed.

i) Functional and Non-Functional Requirements

Functional requirements define what the software system should be able to achieve. The functional requirements are primarily specifications of the services that the system should deliver, how the system should respond to inputs, and how the system should behave in specific situations [21]. Meanwhile, [21] also states that non-functional requirements are the limitations of the software system's services. In contrast to functional requirements, non-functional requirements do not directly describe the exact services of a software system, but rather describe how well the software system performs. The functional and non-functional requirements of the FiSH: Fish Smart Habitat – An IoT Based Smart Aquarium Monitoring Systems mobile application are stated below in Table 11 and Table 12 respectively.

TABLE XI
FUNCTIONAL REQUIREMENT FOR FISH: FISH SMART HABITAT – AN IOT BASED SMART AQUARIUM MONITORING SYSTEMS MOBILE APPLICATION

Functional Requirements	**Description**
Authentication	Users are required to either login or register before being allowed to use the features on the FiSH: Fish Smart Habitat – An IoT Based Smart Aquarium Monitoring Systems mobile application.

Functional Requirements	Description
pH level monitoring	Users can monitor the pH level of water in numeric value. Hence the user can get updates on the pH level and status in real time by only using a smartphone
Temperature Monitoring	Users can monitor the pH level of water in numeric value. Hence the user can get updates on the temperature and status in real time by only using a smartphone
Fish Feeding	Users can operate fish feeding in real-time and remotely fish feeding using a smartphone.

TABLE XII
NON-FUNCTIONAL REQUIREMENT FOR FISH: FISH SMART HABITAT – AN IOT BASED SMART AQUARIUM MONITORING SYSTEMS MOBILE APPLICATION

Non-Functional Requirements	Description
Platform compatibility	FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application will only run on Android platform.
Performance and responsiveness	The application reaction time is prompted by the user's input behaviour and displays appropriate output.
Usability	Since there is no age limitation, it is made simple to ease the understanding and interaction of the users while navigating on the mobile application by considering older people and kids.
Security	The user needs to log in before continuing using the application.
Consistency	The design of FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems application user interface must be consistent.

ii) IT Infrastructure Components of FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

This section will outline the hardware and software requirements for developing the application. This is an essential part to highlight since it helps to ensure that the development process runs well. The list of hardware and software are shown in Table 13 and Table 14 respectively.

TABLE XIII
LIST OF HARDWARE

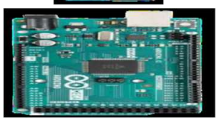
No	Purpose	Hardware	Specification
1	To be able to run Android applications.		Model: Realme 5i Operating System: Android 9 Processor: Octa-Core Memory: 4 GB Storage: 64 GB
2	To control the pH water sensor, continuous servo motor and Wi-Fi module on the FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems		Processor: Atmega2560 Operating Voltage System: 5V Memory: 8KB Flash Memory: 256kb
3	To provide wireless connectivity and enable Internet of Thing (IoT) capabilities of FISH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems		Model: ESP-01S Operating Voltage: 3.3 VDC Wi-Fi Protocols: 802.11 b/g/n protocol Frequency Range: 2.4G – 2.5G Supply Current: 80Ma
4	To measure and monitor the pH level of a liquid on FISH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems		Model: Analog pH Supply voltage: Sensor v2 Output Voltage: 3.3 – 5V Measurement Accuracy: 0 – 3.0V Detection Range: ±0.1@25℃ 0 - 14
5	To measure and monitor temperature in various applications		Model: DS18B20 – Temperature Sensor Supply Voltage: 3.0 – 5V Interface: 1 wire interface Measurement Accuracy: ±0.5℃ to 10℃ Detection Range: 10℃ to +85℃ -55℃ to +125℃
8	To operating feeding of fish food to fish on FISH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems		Model: FS90R Operating Voltage: 4.8V to 6.0V Stall torque & Max Speed: Max Speed @ -6V: 130 RPM to - 4.8 V: 100 RPM Size: Stall torque @ - 6 V: 1.5kg/m - 4.8 V: 1.3kg/m 23.2mm x 12.5mm x 22mm

TABLE XIV
LIST OF HARDWARE

No	Software	Description
1	Android Studio	To develop FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application
2	Google Firebase	To develop a database for FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application
3	Arduino IDE	To program the connection of IoT elements.
4	Canva	To design and edit images used in this project
5	Draw.io	To design flowchart for the project
6	Circuito.io	To create a circuit sketch of IoT components.
7	Moqups	To design wireframe (Lo-Fi) for the mobile application

B. *Designing FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application*

This section is critical for providing some practical guiding principles in creating the FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application in order to meet the second objective of this project. The second objective of the FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application is vital to ensure the process involved in this project moves in a structured way. This objective consists of a few components such as storyboard, IT Infrastructure Diagram, flowcharts, use case diagram and hierarchical diagram to help in designing this mobile application.

1) Storyboard Conception

Storyboarding is a technique of documenting dialog designs by displaying a series of sketches of the display screen. A simple sketch can help users and developers understand the main idea of a dialog design, and consumers are more likely to suggest design improvements when looking at a sketch. Prototyping tools can also be used to implement storyboards. Figure 3 shows the storyboard of FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application.

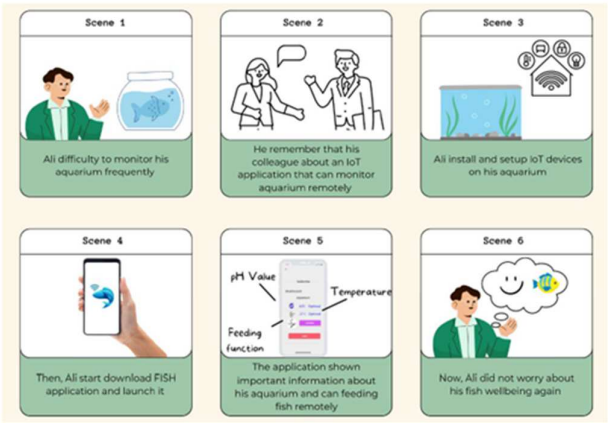


Fig. 3 Storyboard of FiSH – Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems

2) External Device Design

i. IT Infrastructure Technical Architecture Diagram

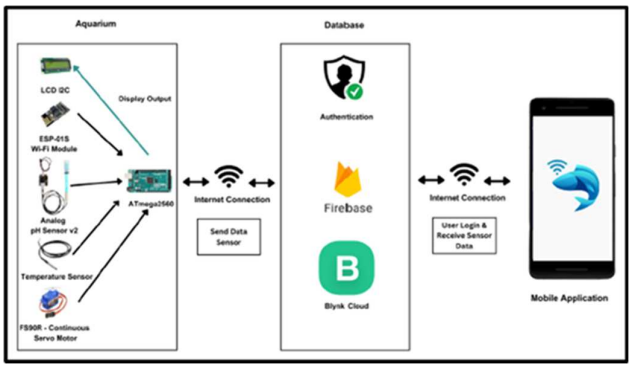


Fig. 4 IT Infrastructure Technical Architecture Diagram

Figure 4 illustrates the IT infra-architecture diagram of FISH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems. The ATmega2560 will relate to 5 types of different hardware which are LCD I2C, ESP-01S Wi-Fi Module, Analog pH Sensor, Temperature Sensor and FS509, a Continuous Servo Motor. Firstly, the LCD will act as a screen of the aquarium to display information of the pH level, temperature and feeding operation. Next, the ESP-01S Wi-Fi module will connect to the internet to send all the data required from all the hardware components to the Blynk Cloud. After that, the ATmega2560 will connect to the internet to send all the data required from all the hardware components to the Blynk Cloud Meanwhile, the firebase authentication will provide backend services, easy-to-use SDKs, and ready-made UI libraries to authenticate users to the application. Lastly, the FISH mobile application will retrieve the data stored in the firebase to login the application and Blynk Cloud to make the features function appropriately.

ii. Circuit Sketch of Arduino Board to Develop FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Aquarium

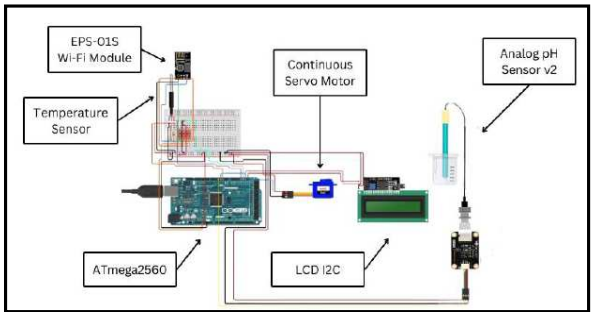


Fig. 5 Circuit Sketch for FiSH– Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems

Figure 5 illustrates the circuit sketch that will be embedded in the FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Aquarium. In this circuit, it will have an ATmega2560 as the microcontroller board, an ESP-01SWi-Fi module, an I2C model LCD, an analog pH level sensor v2, a temperature sensor and also a continuous servo motor. This circuit sketch prototype was designed using

Circuito.io. USB Cable will be used to supply the power to the ATmega2560 board. A breadboard is used to build and test electronic circuits without having to do any soldering. The pH sensor needs to be supplied by 5V power to function by connecting the VCC pin from the pH sensor to the Vin pin of the ATmega2560. Similarly, the LCD I2C needs to be connected by 5V power to produce better visibility on the screen. Temperature sensors are used in this project that will be supplied by 5V power by connecting the VCC pin to the 5V pin of ATmega2560. The continuous servo motor will be supplied also with 5V pin. Lastly, the Wi-Fi module will be supplied with 5V power. The TX pin will be connected to RX1 and RX pin to TX1 pin of ATmega2560.

3) Use Case Diagram of FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

The use case diagram represented in Figure 6 shows the interaction between the user and the system and the use case diagram is usually displayed in an illustration form. Moreover, this diagram shows the actions that can be carried out by the actors and the response that they receive.

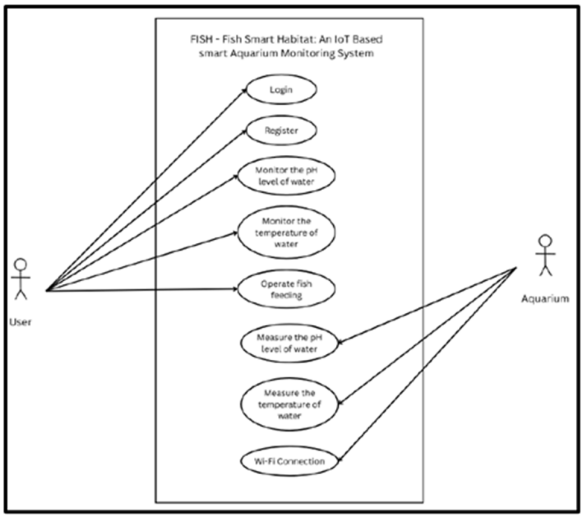


Fig. 6 Use Case Diagram for FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

4) Data Design of FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

i. Hierarchical Model

FiSH -Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application is using a non-SQL database where it is essential to design the database for the development. The data Firebase is used as the database in this project to store data of user's information and the aquarium's data. FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application consists of two root nodes which are User and Aquarium. The User node consists of UserID which stores information such as email address and password. As for aquarium. It stores the aquarium's pH value, temperature and feeding systems status. The hierarchical model is designed with the aid of Draw.io as shown in Figure 7.

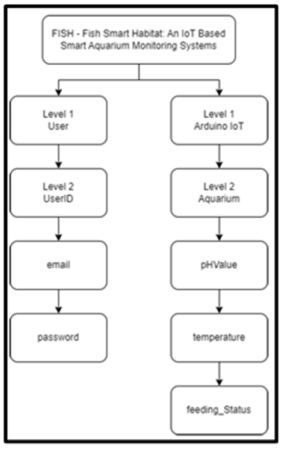


Fig. 7 Use Case Diagram for FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

ii. Data Dictionary

Table 15 shows the Data Dictionary which is a collection of table names, attributes, data type, data format and description about data elements that are being used or captured in FiSH mobile application database. It describes the meanings and purposes of data elements within the context of a project, and provides guidance on interpretation, accepted meanings and representation.

TABLE XV
DATA DICTIONARY

Table Name	Attribute Name	Data Type	Data Format	Required	Description
User	UserID	String	Xxxxxx	Yes	User ID
	email	String	Xxxx@xx	Yes	Email Address
	password	string	>6 character	Yes	User password
Aquarium	phValue	float	9.9999	Yes	pH Value
	temperature	float	9.9999	Yes	Temperature
	feeding_status	int	99999	Yes	Feed Now Status

C. Developing FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

The process of developing the FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application is essential to ensure that it is actually aligned with the requirements that were mentioned previously. The development of the FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application uses Android Studio meanwhile Google Firebase and Blynk Cloud to store the data. Next, the project must be tested to ensure that it runs smoothly, without errors or defects, and displays the correct output. As a result, after development is completed, user testing is required to assess all of the features and functionalities included in the FISH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application for improvement and future enhancement.

1) Front End Development for FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

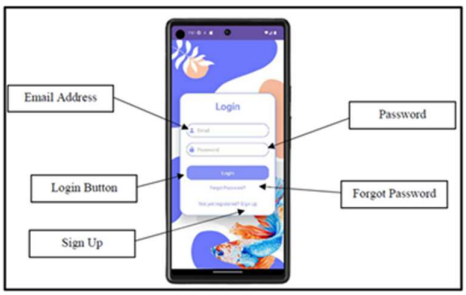


Fig. 8 Login Page

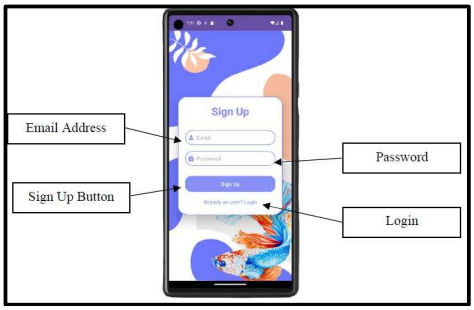


Fig. 9 Registration Page

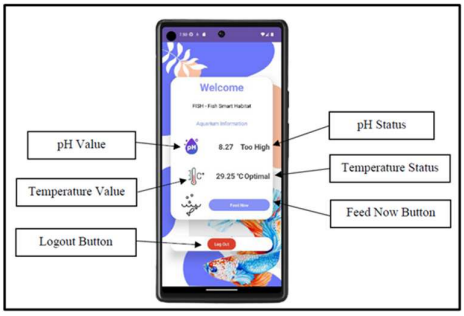


Fig.10 Dashboard Page

2) Back End Development for FiSH - Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

Back-end development is an essential component of a mobile application because it stores, secures, and processes data. A backend application functions similarly to a server, allowing users to sort the necessary information. In other words, it refers to the activities that take place behind the scenes when users use an app to complete a task. Back-end development is an essential component of a mobile application because it stores, secures, and processes data. A backend application functions similarly to a server, allowing users to sort the necessary information. In other words, it refers to the activities that take place behind the scenes when users use an app to complete a task. Meanwhile, Blynk is a cloud-based, hardware-agnostic internet of things (IoT) platform which allows users to connect hardware models with the secure, open source Blynk Cloud via WiFi, 2G-4G, LTE, or Ethernet. In this project, Blynk provides hosted backend services such as a real-time database and cloud storage.

3) External Device Development

There is only one aquarium project available for the FiSH – Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application as for now. The circuit board of the Arduino project and the code for the Arduino project is as shown in Figure 13 below.

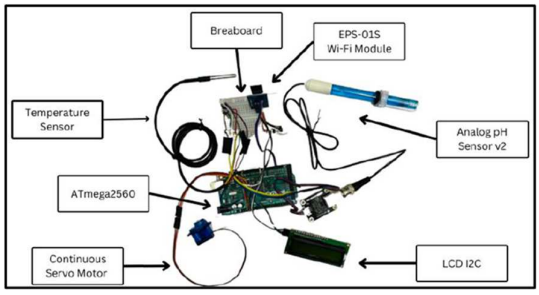


Fig. 11 Circuit Diagram of FiSH Aquarium

The hardware components used to develop Aquarium are ATmega260 as the microcontroller board, an LCD I2C screen, an Analog pH Sensor, temperature sensors, a EPS-01S Wi-Fi module and a Breadboard. The Breadboards are used to connect the component without soldering. This project will require both male to male jumper, male to female jumper and female to female jumper. The connectivity of the jumper from the components pin to the ATmega2560 pin is shown in Table 16 to 18 below.

TABLE XVI
LCD 12C CONNECTION

LCD 12C Connection	
LCD 12C	ATmega2560
VCC	5V/Vin
GND	GND
SCL	SCL
SDA	SDA

TABLE XVII
EPS-01S CONNECTION

EPS-01S Connection	
EPS-01S	ATmega2560
VCC	5V/Vin
GND	GND
RX	TX1
TX	RX1

TABLE XVIII
ANALOG PH SENSOR V2 CONNECTION

Analog pH Sensor v2 Connection	
Analog pH Sensor v2	ATmega2560
VCC	5V/Vin
GND	GND
Output	A1

Figure 14 and Figure 15 show the view of the different angles of Aquarium. The design to develop the kiosk is considered by several factors to enhance the efficiency of the system flow. The main material used to develop this kiosk is cardboard box. The size of the kiosk is 37cm in height and 24cm in width including the stand. Next, there are 2 layer for IoT box on top of normal aquarium. The upper layer has ATmega2560, breadboard, ESP-01S Wi-Fi module and LCD. Meanwhile, bottom layer has Analog pH Sensor v2 and

Temperature sensor. Beside this box is feeder with continuous servo motor that act as feeding systems in this project. Lastly, the LCD screen is embedded in the upper place to ease user to view the pH level and temperature with both status while using the aquarium.

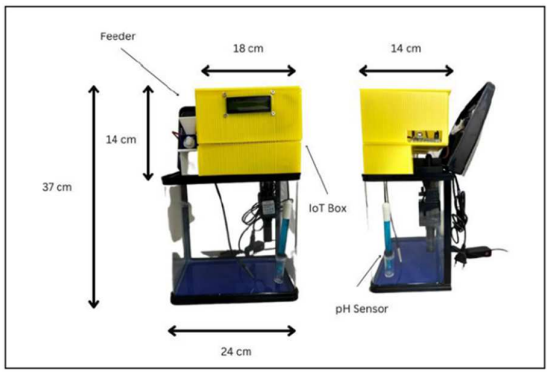


Fig. 11 Front & Side View of Aquarium

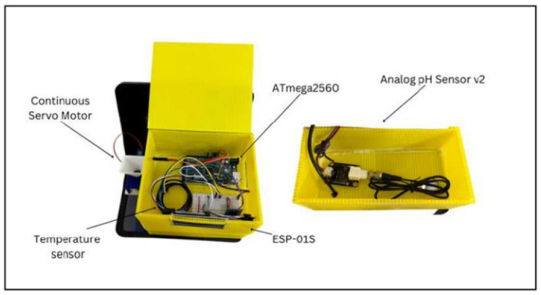


Fig.15 Upper View of Aquarium

4) Systems Integration for FiSH – Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems Mobile Application

This section depicts the sequence diagram for the FiSH – Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application system's integrated fragments. Sequence Diagrams are interaction diagrams that show how operations take place. They record the interaction of objects within the context of a collaboration. Sequence Diagrams are time-focused, and they visually represent the order of the interaction by using the diagram's vertical axis to represent time, what messages are sent, and when. The sequence diagram for user login to the FiSH – Fish Smart Habitat: An IoT Based Smart Aquarium Monitoring Systems mobile application can be seen in Figure 16 to 18.

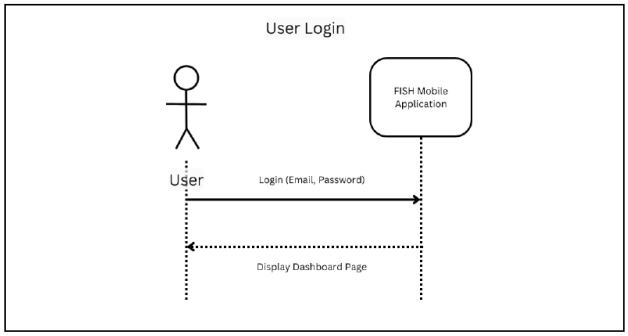


Fig.15 User Login

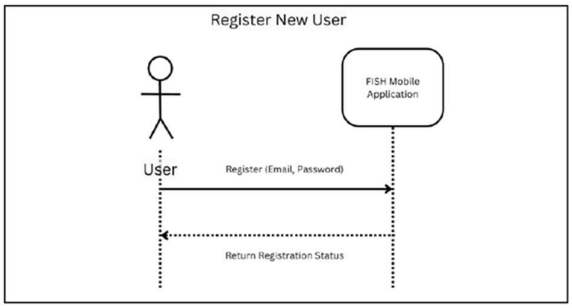


Fig.16 Register New User

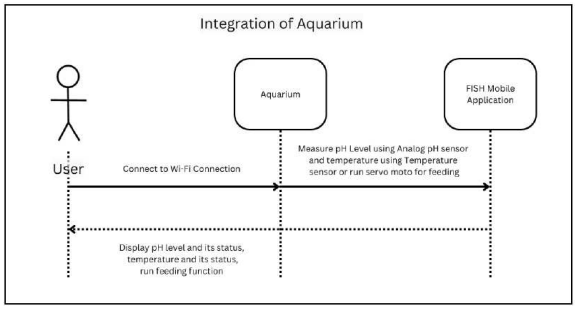


Fig.17 Integration of Aquarium

CONCLUSIONS

The purpose of bringing up the suggestions is to determine the best chances and potential improvements to be made in the near future to FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring System mobile applications. Some suggestions were made to enhance the mobile learning application based on the user testing that was conducted. The following suggestions are as follows:

The aquarium should store optimal ranges for different types of fish and the aquarium feature also needs to provide information on what steps to take if the pH level and temperature are out of range. This will enable users to begin acting in response to the situations they find themselves in.

Allow users to add multiple aquariums through the mobile application. This will give the user the ability to monitor many aquariums in a single time.

Although the FiSH: Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application only focuses on pH level, temperature, and feeding systems, the adjustment can be made by incorporating additional hardware into the board, such as a controllable LED.

According to user testing, the feeder can only support small fish platelets for the time being. The feeder can be expanded in the future by using better material and sizing to accommodate different types of platelets.

Apart from that, the successful development of FiSH - Fish Smart Habitat: An IoT-Based Smart Aquarium Monitoring Systems mobile application will undoubtedly revolutionize the way aquarium enthusiasts maintain a healthy environment for their pet fish. By enhancing fish health and reducing the need for chemical treatments, the app will provide a seamless and effective solution for aquarium care. Additionally, the application's user-friendly features will empower users to monitor their aquarium items effortlessly, ensuring a stress-free experience. The future holds immense potential for further improvements and deeper focus on enhancing the

app's capabilities, fostering a fish owner community of environmentally conscious individuals. Embracing this technology will not only minimize maintaining costs but also stimulate growth development for fish, ultimately contributing to a healthier and more sustainable way for keeping an aquarium.

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