MJSAT

Malaysian Journal of Science and Advanced Technology

journal homepage: https://mjsat.com.my/

Improving Fish Quality and Yield: An Automated Monitoring System for Intensive Aquaculture

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KEYWORDS

Fish Monitoring System
Arduino
Fish farm
Internet of Things
Sensors

ARTICLE HISTORY

Received 15 March 2024
Received in revised form 30 March 2024
Accepted 4 April 2024
Available online 6 April 2024

ABSTRACT

The growing interest in the fish farming industry is driven by the depletion of natural fish stocks in the market. However, intensive aquaculture systems, which involve raising fish in artificial tanks and cages, can lead to challenges such as low-quality fish and increased mortality rates, depending on the species being cultivated. To address these issues and maximize yield, this paper proposes a fish quality monitoring system with automatic correction. The system focuses on monitoring and maintaining critical water quality parameters essential for fish growth, including temperature, water level, and pH level. The system comprises an Arduino connected to sensors and a web-based application for data collection and monitoring. Correction devices such as an aquarium heater, a valve, and a water pump are integrated into the system to maintain these parameters at optimal levels for fish development. To assess the system's efficiency and reliability, two fish monitoring setups were compared: one using the proposed controlled system and the other using a traditional setup. Results indicate that the controlled system increased efficiency, reduced stress on fish farmers, decreased fish mortality rates, and improved product quality compared to the traditional setup.

1. INTRODUCTION

The Fish Monitoring System is designed to aid with pond water quality management. The systems continually track and monitor water quality, giving thorough data that can be done on-site in conventional methods for monitoring water quality. Testing and measurements of water are carried out in a way that restricts the data to the precise moment that it was obtained. More advanced techniques include computers and sensors that can store data in memory for subsequent retrieval and analysis by technicians [1]. Currently, water monitoring systems use two different types of control techniques. A general-purpose system to check the water status manually. The other is an industrial control system that owners' controllers and small-scale, programmable computers. Different water parameters may be monitored by both systems. Currently, water treatment plants employ these systems. Hence, application of Internet of Things (IoT) technology in fish monitoring system for pond quality management is a feasible solution to monitor quality of water for treatment plants.

The network of physical items, or "things," integrated with sensors, software, and other technologies that allow them

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https://doi.org/10.56532/mjsat.v4i2.296
2785-8901/

to communicate and exchange data with other devices and systems over the internet is known as the Internet of Things (IoT) [2]. These goods can be anything from commonplace things like wearable technology and home appliances to large-scale industrial machines and infrastructure elements [3]. These items may gather and communicate data about their surroundings, activities, and status thanks to Internet of Things technology, which makes it possible to monitor, control, and automate a variety of processes in real time. IoT has the power to completely transform a wide range of industries, including manufacturing, transportation, healthcare, agriculture, and smart cities. This is because it allows devices to communicate with each other seamlessly. IoT promises to increase productivity, maximize the use of available resources, improve decision-making, and open up new avenues for innovation and company expansion. Therefore, IoT is extensively utilized for smart control and optimization in a variety of domains [4-7]. Using energy harvesting as an example, IoT is utilized. Energy-harvesting technologies like solar panels, microbial fuel cells [8-10], and plant microbial fuel cells [11–13] are integrated with sensors and devices to employ it in energy harvesting. Instead of using conventional batteries or wired power sources, these Internet of Things gadgets may take energy from their surroundings, such as sunlight, vibrations, or temperature differences, to power themselves. The range of monitoring and control applications is thereby expanded as this makes it possible to deploy IoT sensors in difficult-to-reach or distant areas where standard power sources are unfeasible or unavailable [14]. In order to power sensors, the Internet of Things is combined with energy harvesting. Powering sensors is an important factor to take into account in Internet of Things applications, especially in distributed or remote contexts [15]. In order to reduce energy consumption, Internet of Things devices frequently use wireless communication protocols and low-power microcontrollers [16–17]. To extend battery life, energy-efficient design concepts like duty cycling and sleep modes are also used. Furthermore, as was already indicated, developments in energy harvesting technologies help power IoT sensors without requiring regular battery changes or cable connections to the grid for electricity [18–21].

1.1 Background Study

Aquaculture is the world's most significant and fastest-growing business for animal food production, and it is the primary source of aquatic animal food for human consumption. As far as aqua cultured fish are concerned, because the system relies on water in an artificial tank to survive, feed, develop, and excrete waste, the water quality quickly degrades, posing a threat to the system's growth and health. Water quality indicates accomplishment or disappointment to an exorbitant degree of aquaculture. Since a result, water quality is an important consideration in fish monitoring operations, as it ensures the health of any aquaculture system. Maintaining water quality in the optimal range promotes fish development and decreases the occurrence of fish illnesses [22]. Temperature, water level, and pH are just a few of the critical water factors to keep an eye on. Temperature, potential hydrogen (pH) level, water level and are all important water factors to monitor and manage. To monitor the condition of numerous water quality factors, fish breeders rely on manual testing. Manual testing, on the other hand, takes time and produces inaccurate findings since water quality fluctuates over time. As a result, cutting-edge technology should be applied to address this issue in this monitoring system. Mechanization of aquaculture setups will provide the following benefits: production closer to market demand, improved environmental standards and directives, reduced devastating losses, decrease environmental management, lower production costs, and improved aquatic product quality. The water temperature, pH, water level, are all monitored and automatically corrected by the system. Sensors, LoRaWAN (Long Range Wide Area Network), and correction devices are all used in this system [23]. The threshold values for the distinct water quality measures are pre-programmed in the micro-controller. Motors attached to micro-controllers, water pumps, are used to create improvised correction devices. Water replacement is used to stabilize the water quality and to stabilize the pH level. This allows the water to be adjusted to a suitable temperature for fish development without exposing the fish to chemicals that might harm their health. Furthermore, for fish growers, this technology is far less expensive and simpler to implement. The data from the sensors was only collected once a day or it alarms the user when the sensor triggers. The data collection is done at a specific time of day, and the correction is done after the data collected is not within the necessary range for fish growth.

1.2 Problem Statement

The fish farmers must visit the farm several times every day to supervise the overall activity. Workers visit the aqua farm on a regular basis to examine the pond's water quality as per their timetable. Some people use portable metre to manually check water parameters, while others submit a water sample to a laboratory for testing. In comparison to other fields of technology, such as agriculture, aquaculture is behind. As a result, it is critical to use technology to help solve the difficulties. Although manual monitoring is beneficial in that farmers can directly examine and know the health state of the fish, checking on a regular basis will require a lot of time and work. The main issue for fish farmers is the water quality, which is essential for a healthy fish. These three categories are water level, temperature, and ph level. Fish can escape from a pond or aquarium when the water level is too high or suffer when the level is too low. The health of the fish may be harmed by excessively hot or low temperatures, which may result in fish skin disease Columnaris or even death. High pH values can affect fish health, resulting in symptoms such as frantic swimming, lethargy, rapid breathing, or other erratic behaviour and eventual death for the fishes which is term as the disease call Hemorrhagic Septicemia.[24-27] Low pH levels also harm fish by generating tuberculosis. To create a healthy fish, producers must constantly evaluate these important factors.

1.3 Objective

The objectives of this study are to use Arduino micro controller to be integrated with three sensors which are temperature sensor, water level sensor and pH level sensor and to apply temperature sensor to measure high and low water temperature and to trigger the water pump to pump in water into the tank through first hose and to pump out the existing water from tank through second hose when the temperature is above 30℃ and alert the user when the temperature is below 25℃ in fish monitoring system. Besides that, the project is also aim to apply pH level sensor to measure high and low pH value of the water and to trigger the water pump to pump in water into the tank through the first hose and to pump out the existing water through the second hose when the pH level indicates high value which is above 9.0 and low value which is below 6.0 in fish monitoring system as well as to apply water level sensor to measure high and low water level and to trigger the water pump to pump in water into the tank when the water level is below the optimal level in the fish tank in fish monitoring system.

1.4 Literature Review

Monitoring Smart Fish Farm Implementation by employing sensors and networks instead of the conventional way, IoT increases operational effectiveness and system application flexibility while at the same time lowering the cost of labour. The practical application gave the gateway the thumbs-up for smooth operation in the monitoring system. This concept makes use of remote intelligent monitoring to operate the fish farm and assist the owner in conducting scientific water quality monitoring [28]. To gather the data from each sensor, the system created and deployed an automated aquarium system. This system was created to monitor and manage the environmental conditions required to meet a fish's ideal demands. putting in place a mobile app, a service platform, and a control module on an IoT gadget so the user may manage the water system from a distance. Our technology is anticipated to be a potential tool for farmers looking to enhance the output of high-quality fish in an efficient fish farming system. The farmers now need a technology that will display the status of these factors in real time. Even farmers lack reliable knowledge of when the water's condition changes [29 - 33]. The suggested system will frequently check for these changes and either automatically take action or have the farmer pretend to do it. The system will have a feature to display all of the streaming data from the fish monitoring system graphically. Later, a farmer may use a smartphone to control the equipment from a distance.

A smart aquarium device was designed to feed aquaculture fish automatically, namely Smart Aquarium Design Using Android-Based Raspberry Pi, designed to provide convenience in the process of maintaining fish in an aquarium and to change water [34]. In another research, a manual work and labour-saving system is automated for monitoring of fishes with predetermined number of certain sensors at the decided time [35]. Furthermore, research in [36] presents a remote monitoring system using the concept of IOT for aquaculture water quality. In future the sensors will be submersed in water for the entire farming system as the data would be helpful before harvesting and some other important sensors can also be added if required according to the environment.

A smart monitoring and automation control system for a fish aquarium is created. The prototype applies Internet of Things technology, so the fish keepers can adjust the fish needs (water and feed) remotely anywhere and anytime. The system has temperature and turbidity sensor, automatic water drain, and live stream features.[37]. Besides that, an automatic fish feeder is a device that automatically feed the fish at a predetermined time. In a way, it is to control the fish feeding activity by using a fish feeder that combined the mechanical system and electrical system to form a device instead of manually feeding the fish by hand [38]. In another research article in [25], this study automates the system and decrease manual labour by using specified number of specific sensors to monitor the fishes at a predetermined time.

In addition, one research attempts to develop the thermal energy management system of warm water energy that is utilized in a fish farming systems based on Internet of Things (IoT). It had developed a remote control and monitoring system of a smart fish farm by using IoT technology [39]. A fish farm monitoring and automation control system is developed. The prototype makes use of Internet of Things technology, allowing fish caretakers to change the fish's demands (water and feed) from anywhere and at any time. Temperature and turbidity sensors, an automated water drain, and a live broadcast are all included in the system [40]. The proposed work supports remote monitoring of the fish farming system based on Internet of Things (IOT) for real- time monitor and control of a fish farming system. The system uses various sensor along with multiple sensors that require in fish farming industry to sustain the health of water cultures.

2. METHODOLOGY

This project's technique makes use of an Arduino Uno as well as the key three sensors for this fish monitoring system. For electronic components like the pH sensor and temperature sensor to function, the Arduino uno was pre- programmed with instructions using the Arduino Software. To measure the features of the water quality, the sensors were utilized. Using monitoring software, the data was logged into a smartphone, and then it was provided to customers. This tiny prototype functioned as a floating platform that the entire system could use to go around the culture tank. The water level sensors are put in the pond system to monitor the water level and water quality in this suggested system of IoT based fishpond keeping system. The pH sensors are installed in the pond system to monitor the water's pH level. The temperature sensor will display the water temperature in the pond or fish farm. Each sensor is programmed with the original optimal value to determine high and low levels and act accordingly.[41]

2.1 Level of Complexity

Fish, like many other things, have a specified tolerance range for certain environmental parameters, particular types of fish farming necessitate the fulfilment of conditions in order to be successful. In addition, to maintain a healthy habitat for the live fish, workers who are employed in fish farming ponds are required to remain active during the whole workday. The primary purpose of this article is to monitor and take steps to preserve the habitat's sustainable environment for fish species inside of fishing ponds through distributed machine to machine communication. This will reduce the amount of time necessary for some key procedures. [42]. Within the scope of this study, we contribute an enhancement to an operational Internet of Things (IoT) system for monitoring fish farming systems. The Internet of Things system consists of a small board computer that processes the data and sends audible and visual signals to the management of the fish farm, as well as many sensors that detect important aspects of water quality such as temperature, pH level, and water level. The technology that is currently in place is unable to process data and make it available to users via mobile or web platforms. End users will be able to monitor and manage components of the Internet of Things system for fish farming ponds in real time if an extension module, such as a modem, is utilised. This is one solution to the challenge presented by the remote location of fish farming ponds and their reliance on pure fresh water. Additionally, the fact that there are four connected sensors that are supplying outputs to the system is another factor that may help to explain the complexity of this project. [43] This should ensure that the failure of a single sensor does not influence the functioning of the entire system.

2.2 Tools and Procedure

- *Hardware*

a. Arduino Uno

The Arduino Uno is a microcontroller that has 14 digital input/output pins in addition to 6 analogue inputs. It is also capable of being powered by an external power source, such as a battery or an AC-to-DC adapter, in addition to being powered by a computer through a USB connection. For the board to function properly, the voltage supply must be within the range of 7 V to 12 V. The Arduino Uno can be programmed using the software that comes with Arduino. C++, a language known for its friendliness to programmers, serves as the foundational language for Arduino software. This intuitive programme is compatible with the Windows operating system. In comparison to Raspberry Pi, Arduino Uno is available at a lower cost, which was a factor in our decision to go with it. When compared to Raspberry Pi, the software that comes with Arduino is easier to work with. In addition, the software is distributed as open-source tools, which makes it much simpler for consumers to comprehend the platform's technological underpinnings. Users are able to cut down on the amount of time they spend developing and debugging their software thanks to open-source code contributed by expert programmers. [44]

b. Water Level Sensor

In a stationary container, an abnormally high or low water level can be detected by a sensor known as a water level. It is classified as either a contact type or a non-contact type, and this distinction is based on the method that is used to measure the liquid level. The submersible level sensor determines the amount of liquid that is contained within the tank. The greater the amount of water that the sensor is submerged in, the greater the conductivity of the water, which in turn will result in a lower resistance. The lower the amount of water in which the sensor is submerged, the lower the conductivity of the sensor, which in turn will result in a larger resistance [45].

c. Temperature Sensor

In the design that has been proposed, a temperature sensor that is waterproof DS18B20 is used. It is a waterproof digital temperature probe that may be submerged in any liquid without leaking or breaking. Because the DS18B20 has a 1-Wire interface, it is only necessary to connect a single wire from the Arduino to it. The temperature probe has an accuracy of 0.5 degrees Celsius and can monitor temperatures ranging from -55 degrees to 125 degrees Celsius. The sensor's output voltage is going to be measured to obtain the temperature from the sensor. Because the sensor generates an analogue voltage, the wire will be linked to the analogue input pin on the Arduino [46].

d. PH Level Sensor

When it comes to testing water, one of the most critical pieces of equipment to have to be the pH sensor. This type of sensor can determine the levels of alkalinity and acidity in water as well as other liquids. The aquarium hydroponic spare laboratory pH electrode probe BNC connector was the instrument that was utilised in the process of determining the pH value of the liquid that was being tested. It has an accuracy of 0.1 pH and can measure the pH range from 0 to 14 over a temperature range of 0 to 60 degrees Celsius in water. A pH sensor circuit board is required to connect to an Arduino board because the electrode probe is attached with a BNC connector. Due to the fact that the pH sensor generates an analogue output signal, it will be linked to the analogue input pin on the Arduino. [47]

e. Water Pump

Within the context of this system, the process of water replacement is crucial to the transformation of the overall water quality. In this intelligent fish monitoring system, an R385 DC12V Diaphragm Water Pump is utilised. Bubbles are produced because of the pump drawing in air and then releasing it into the water. The water is displaced by the bubbles, which churns the water and causes the carbon dioxide to ascend to the surface. External pumps deliver air to the pump by means of a hose that is connected to the pump itself when it is submerged in water. [48].

f. 1Sheeld+

1Sheeld+ is a framework that enables Arduino to employ the sensors and capabilities of smartphones in a variety of different Arduino projects. The difference between the original version 1Sheeld and the 1Sheeld+ is that the latter is compatible with both Android and iOS devices, whilst the former was only compatible with Android devices. In its most basic form, 1Sheeld+ is made up of two components. The first component is the physical board, which includes a micro controller and a Bluetooth module for the purpose of data transmission between an Arduino and a smartphone. It is positioned directly on top of the Arduino board and may be powered and controlled by the same source of electricity that is used to run the Arduino Uno. The mobile application that may be used on a smartphone and the accompanying software platform make up the second component. It allowed communication between the 1Sheeld+ and smartphone, both of which were functioning as virtual shields for Arduino. [49]. Table 1 shows the expected number of hardware needed for the project.

Table 1: The expected number of hardware needed forthe project.

Hardware	Expected Quantity
Arduino Uno	1
Water Level Sensor	1
Temperature Sensor	1
PH Level Sensor	1
Water Pump	2
Relay Model	2
1Sheeld+	1
Jumpers	Based on project
Circuit Board	2
Switch	4

- *Software*

a. Arduino Software (IDE)

The Arduino Software is an open-source Integrated Development Environment (IDE) that enables users to create code and then upload that code to an Arduino board. Users can access a variety of tutorials in order to gain a better understanding of the software's more technical aspects thanks to the fact that the Arduino IDE is an open source and extendable programme.

b. 1Sheeld App

1Sheeld+ is able to connect the Arduino to 1Sheeld's own apps running on smartphones through the use of Bluetooth thanks to the software platform. 1Sheeld+ gives you access to over 40 different shields to choose from. The 'Data Logger Shield,' 'Email Shield,' and 'Push Button Shield' are the names of the several shields that were utilized in the construction of this system. The 'Data Logger Shield' is used to log data into the memory of the smartphone; the 'Email Shield' is used to email the logged data to other users; and the 'Push Button Shield' enables the user to determine when to start logging the data.

2.3 Procedures

Figure 1 summarizes the methodology of the project. The scope of research was selected in order to have a general notion of how to carry out the project. Journals and articles from different researchers were examined and collated in order to improve and adapt present monitoring system technology. After reviewing the features and components employed by previous studies, a conceptual design was presented. A prototype design of how the system will operate was created.

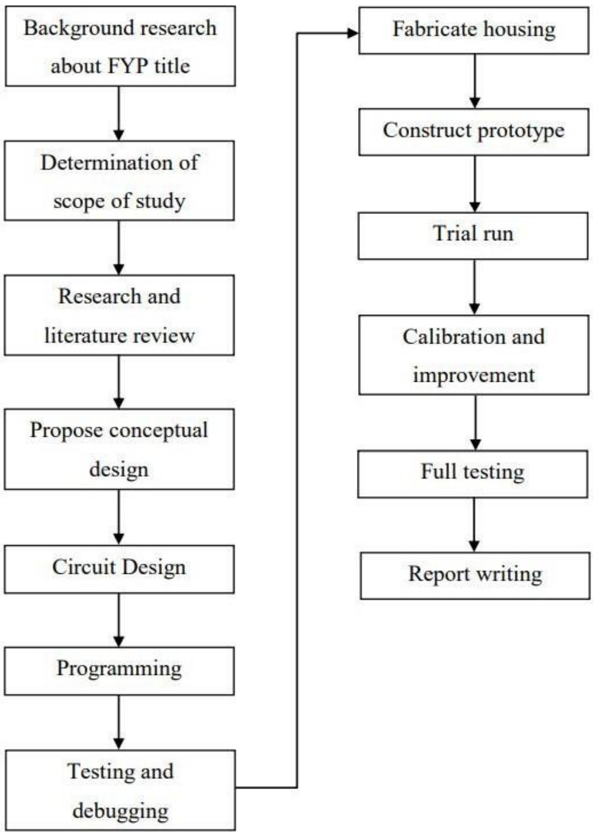

Fig. 1. Flowchart of the methodology

- *Initial Requirements /Background Research Design*

Initial project confirmation had entailed determining the quantity and type of sensors. Then, to gather further project experience, preliminary study and reference materials were performed. The project start date, scope, task limitations, resource and manpower constraints, project environment, deliverables, and budget are all defined criteria. To comprehend the project title, much research has been conducted.

- *Literature Review*

A minimum of 30 articles and associated links from expertise and past work reviews were investigated. A literature review is essential in a research paper since it serves as proof to support the project title and shows that a background of the system has been carried out previously. All of the articles have been screened, and the important elements have been identified for inclusion in the project.

- *Proposed Conceptual Design*

The project's foundational design includes several diagrams that collectively depict the strategy and operational flow of the solution. To define the system, a block diagram and flowchart are developed. Furthermore, the project encompasses planning for ideas, methods, resources, and deliverables throughout its duration.

- *Prototype Development*

The fish monitoring system's model was constructed to mirror its intended manufacturing process, incorporating aspects such as color, graphics, packaging, and instructions. Prototyping, a critical phase in the creation process, involves creating a three-dimensional representation of the concept. Concurrently, the circuit design will be developed alongside the programming installation. Subsequently, the system will undergo testing and debugging, followed by the commencement of the exterior manufacturing process.

- *Testing*

It is important to test the prototype with actual users before beginning development so that design choices may be validated. The goal of the development process is to identify potential issues and areas of opportunity for enhancement at an early stage. This will allow you to construct a product that satisfies the requirements of users and lives up to their expectations once those issues and opportunities have been resolved. This test run helps in the modification of faults as well as the settlement of challenges that were experienced by users. It is able to improve the efficiency with which the system is used.

- *Operation*

If the system returns a negative result, the prototype should return to the rough design to identify and correct the problem. If the system responds well, you may go on to the final design and create a suitable version of the model with a presentable appearance. A final testing should always done before proceeding to final design submission. A development project should be intended to provide a certain outcome with the goal of improving a group's economic and social situations. During this procedure, you can make more changes.

Additional ideas, creativity can be implemented during this process such as adding extra sensors.

- *Final Implementation*

The final project design process should turn the preliminary design drawings into a complete set of final design drawings (construction drawings) and technical requirements for the project. The process of turning strategies and plans into actions in order to achieve previously stated strategic objectives and goals is known as implementation. The strategic plan's implementation is just as critical as, if not more important than the previous strategy. It is important the system has achieved all the objectives stated above.

2.4 Block Diagram

The proposed system included temperature sensors, pH sensors, and water level sensors, all of which were used to measure the water temperature, pH value, and water level between the tank wall and the water quality monitoring system, respectively. These sensors were used to measure the water temperature, pH value, and water level between the tank wall and the water quality monitoring system. The data from the sensors was collected by an Arduino Uno, which operated as a CPU. The Arduino Uno was powered by a 9V battery pack because it can accept an external supply of any voltage between 6V and 20V. In order to transfer data from Arduino to a smartphone, a 1Sheeld+ was placed on top of the Arduino board, and it is connected through Bluetooth to the 1Sheeld app. [35] The 1Sheeld software was utilised in order to log data collected into the memory of the smartphone, after which it was emailed to other users. The proposed structure is depicted in the block diagram that may be found below. A temperature sensor, a pH sensor, a water level sensor, an Arduino Uno, a 1Sheeld+, and two DC motors make up the block.

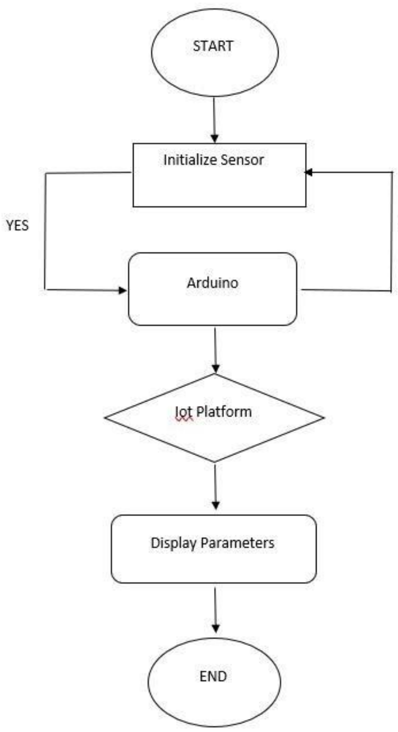

Fig. 2. Flowchart of the system

3. RESULTS AND DISCUSSIONS

In this project, the Arduino Uno replaces the Raspberry Pi, which is rarely utilised in IoT applications. This is because, despite its complexity, employing several sensors on the Arduino will be more efficient. This system is made up of basic monitoring sensors such as water level, temperature, and pH level, but they have been combined in an unusual method to make it more useful in a short amount of time [50]. Furthermore, this system combines various sensors into one to do the same multiple functions. Figure 3 below demonstrates the proposed schematic design, and it shows how the sensors were integrated into one system to collect all of the data from the monitoring systems and communicate it to the user. Control, optimization, and data acquisition are the three components of the system. This trio serves a specific purpose in the operation of the complete system.

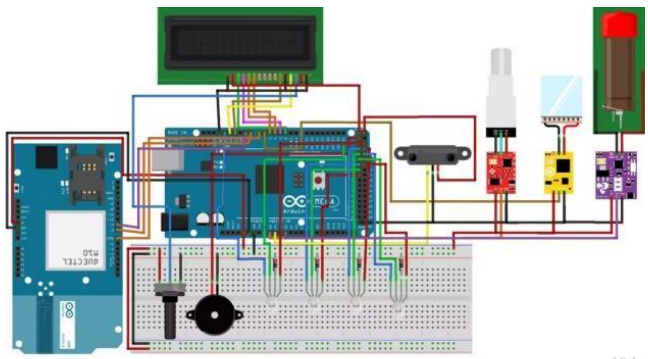

Fig. 3. Schematic design of the proposed system

As previously discussed, fish farmers employ conventional methods and techniques, as well as forecasting models to assess water quality factors. This system has provided all options for avoiding traditional methods and saving labor time. This system's primary goal is to offer real-time monitoring with the water level fixed in the system should be able to take accurate readings and switch on the water pump when the level drops or is required [51]. On the other hand, a pH level indicator should alert the user to the precise pH level in the water so that the user may adjust or balance it and trigger the water pump when the readings reach too low or high to change the water in the tank. Temperature sensor, like pH level, will always display the farm temperature in degrees Celsius in the user application [52]. The example prototype of this fish monitoring system employing the principal three sensors is depicted in Figure 3. This prototype will be tested for output before being integrated with many sensors.

Figure 4 below shows the prototype made for this system. Since the suggested system is intended to monitor the quality of home water, sensors are directly interfaced to the controller. By putting the sensor inside the aquarium, the sensor's parameters, including temperature, salinity, water level, and pH, are monitored. The blynk programme, which is installed on devices to track the levels of water quality, may be used to display the observed parameters. To operate, this application must be connected through Wi-Fi and is programmed on the same platform as an Arduino.

(a)

(b)

Fig. 4. Proposed prototype outlook with top view in (a) and rear view in (b)

According to the three objectives layout all the sensors should be able to read lice results and notify the users at time to time. The results below show the reading taken at a particular time and all the sensors is tested by creating artificial factors. The findings from the fish tank on two distinct days are shown in tables 1 and table 2. On each day, all the results were collected three hours apart. Results from Table 1 show ideal water quality with no changes to any of the four parameters. Table 2, however, demonstrates that each of the components has undergone small variations throughout time. The system's sensors and water pump are tested and activated because of this. Periodically, all adjustments and water quality levels are communicated to the user-connected device.

Table 2. Day 1 results without changing any states

Time (Day 1)	Temperature (C)	pH Level	Salinity Level (PPT)	Water Level (CM)
8.00 am	26.0	6.80	32	Normal
11.00 am	26.0	6.86	32	Normal
14.00 pm	29.0	6.81	34	Normal
17.00 pm	28.0	6.85	35	Normal
20.00 pm	25.5	6.80	32	Normal
23.00 pm	26.0	6.87	36	Normal

Table 3. Day 2 Results with some changes in tank to trigger the pump.

Time (Day 2)	Temperature (C)	pH Level	Salinity Level (PPT)	Water Level (CM)
8.00 am	26.0	6.80	31	Normal
11.00 am	26.0	4.89	32	Normal
14.00 pm	30.0	6.81	34	Low
17.00 pm	28.0	6.85	35	Normal
20.00 pm	25.5	6.80	36	Normal
23.00 pm	26.0	6.87	36	Normal

As shown in table 2, the water pump is activated when the condition of the water tank changes, bringing the water level back to normal. This water pump switch has two settings: manual and auto, meaning that it may be temporarily changed to auto for fluctuations in water level and manual for other circumstances. This is so because a fish tank's water level is a crucial component. The water level must be at the appropriate level for fish to be healthy and living. The user may still take into account additional variables like temperature, salinity, and pH to determine whether or not water needs to be changed. All the environmental stimulus which are measured are shown in the application on phone developed in figure 5. The application software can monitor the temperature, water level, salinity and the pH level with real time monitoring for the farmers to alert them any abnormalities if happen to enable quick action to sustain the fish livelihood in the fish farm.

Fig. 5. Application to monitor the environment stimulus for the IoT Fish Monitoring System.

4. CONCLUSION

Any industry is suitable for the development of Internet of Things technologies. The incorporation of Internet of Things technology into fish monitoring systems is one of these. The idea of a smart aquarium comes from the merging of aquariums with Internet of Things (IoT) systems. A fish monitoring system is a developing and genuine concept for the world of modern maintaining fish that mixes aquaponics with internet of things technology. This concept is quite comparable to it. The development of a clever microcontroller-based instrument for measuring water quality has been fruitfully completed. [34]. It was possible for the device to cover the entirety of the aquaculture tank as long as it was operated in a continuous fashion. Because of this, measurements can be taken at any given location within the tank. The monitoring system was able to measure many aspects of the water in the aquaculture tank, such as the temperature and the pH value. It was able to move on its own and get away from the tank that was being contaminated. The system will not become stuck anywhere within the culture tank under any circumstances. As a result, the characteristics of the water's quality can be measured at various points throughout the aquaculture tank. The Arduino Uno served as the microcontroller, and a 1Sheeld+ was utilised to transport data wirelessly through Bluetooth between the Arduino and the smartphone. The sensors and motor were controlled by the Arduino Uno. Users were able to receive updated data via email after the sensor system was integrated with the Internet of Things (IoT).

If more time and money are allocated to this project, then this fish monitoring system has the potential to be enhanced. The addition of additional sensors to the system, such as ammonia sensors, dissolved oxygen sensors, and water level transducers, is one of the ways in which the system can be improved [53]. As the level of ammonia and the value of dissolved oxygen are just as significant as the pH value and the temperature in an aquaculture tank, the parameters ought to be examined in order to have an improved ability to monitor the condition of the fish. In addition, an Internet Protocol (IP) camera, which can be used for surveillance purposes, can be put on the system. An IP camera enables the video recording to be transmitted or received through a computer network as well as the Internet. By using a smartphone, users are able to observe in real time not only the movement of the fish within the aquaculture tank but also the environment around the tank. Another suggestion for an upgrade is to add a Wi-Fi module to the system so that it can be used to construct a system that monitors the water's quality in real time. Users can check data in real time through a customised app without having to place their smartphones near the system. In addition to that, it is strongly recommended that wireless sensors be implemented to simplify the process of wire connection as much as is humanly possible. Switching out the Arduino Uno with a PIC microcontroller, which is significantly more compact than an Arduino board, is one way to enhance the functionality of the device. There is room for improvement in the dimensions of the housing. If the moving object in the tank is of a smaller size, then the fish in the tank will be less readily frightened by it. The water quality monitoring system is able to be powered by environmentally friendly energy sources like solar power. Solar power would assist to reduce the amount of waste produced by electronic devices because AA batteries cannot be recycled. Additionally, it is not necessary to replace the batteries on a regular basis.

For future works, the integration of artificial intelligence, machine learning, and Internet of Things (IoT) presents immense potential for advancing fish farming practices through the development of an IoT Fish Monitoring System. Future endeavours could focus on refining predictive analytics models utilizing machine learning algorithms to optimize feeding schedules, monitor water quality parameters, and predict disease outbreaks [54]. Additionally, further exploration into leveraging AI-driven image recognition technology can enhance fish health assessment and automate stock monitoring processes. Integration with more IoT devices such as sensors and actuators can enable real-time data collection and automated response mechanisms, facilitating proactive management of fish farms [55-56]. Overall, continued research and implementation of these technologies hold promise in revolutionizing the fish farming industry, improving efficiency, sustainability, and ultimately, global food security.

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