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Full Length Research Paper

Enhancing Fish Quality and Yield: An Automated Aquaculture Monitoring System

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A The market's declining natural fish stocks are the main cause of the increased interest in the fish farming sector. However, depending on the species being raised, intensive aquaculture systems—which raise fish in artificial tanks and cages—can result in problems including low-quality fish and higher death rates. This research suggests a fish quality monitoring system with automatic correction to handle these problems and optimize productivity. Temperature, water level, pH level, and other vital water quality factors that are necessary for fish growth are the major emphasis of the system. The system consists of a web-based application for data gathering and monitoring, as well as an Arduino with sensors attached. To keep these parameters at ideal levels for fish development, correction devices like a water pump, valve, and aquarium heater are incorporated into the system. Two fish monitoring settings were compared, one using the suggested controlled system and the other using a conventional setup, in order to evaluate the system's effectiveness and dependability. Comparing the controlled system to the conventional setup, the results show that it enhanced product quality, cut fish mortality rates, lessened stress on fish farmers, and boosted efficiency.

Key words: Fish Monitoring System Arduino Fish farm Internet of Things Sensors.

INTRODUCTION

Frill The Fish Monitoring System is intended to help regulate the water quality in ponds. Water quality is continuously tracked and monitored by the systems, providing comprehensive data that may be gathered on-site using traditional water quality monitoring techniques. Water tests and measurements are conducted in a manner that limits the data to the exact moment of collection. Computers and sensors that can store data in memory for later retrieval and analysis by technicians are examples of more sophisticated methods [1]. There are now two basic kinds of control methods used in water monitoring systems.

A all-purpose system for manually checking the water's condition. The second is an industrial control system that uses small, programmable computers and owners' controllers. Both systems may monitor different water parameters. These systems are currently used in water treatment facilities. Therefore, a practical way to keep an eye on the water quality for treatment facilities is to use Internet of Things (IoT) technology in fish monitoring systems for pond quality control.
The Internet of Things (IoT) is a network of physical objects, or "things," that have been equipped with sensors, software, and other technologies that enable them to exchange data and communicate with other systems and devices via the internet [2]. These commodities can range from everyday items like household appliances and wearable technologies to massive industrial machinery and infrastructural components [3]. Thanks to Internet of Things technology, these objects may collect and share information about their environment, actions, and condition. This allows for real-time monitoring, control, and automation of a wide range of processes. Numerous industries, including manufacturing, transportation, healthcare, agriculture, and smart cities, could undergo radical change as a result of IoT. This is due to the fact that it facilitates smooth communication between devices. IoT promises to boost output, make the most use of resources, enhance decision-making, and create new opportunities for business growth and innovation. As a result, IoT is widely used for intelligent control and optimization across many different fields [4–7]. IoT is used, for instance, in energy harvesting. In order to use energy harvesting, sensors and devices are combined with energy-harvesting technologies such as solar panels, microbial fuel cells [8–10], and plant microbial fuel cells [11–13]. These Internet of Things devices may use energy from their environment, such as sunlight, vibrations, or temperature variations, to power themselves rather than traditional batteries or wired power sources. This broadens the scope of monitoring and control applications by enabling the deployment of IoT sensors in remote or hard-to-reach locations where conventional power sources are impractical or unavailable [14]. Energy harvesting is integrated with the Internet of Things to power sensors. In Internet of Things applications, powering sensors is a crucial consideration, particularly in remote or distributed settings [15]. Low-power microcontrollers and wireless communication protocols are commonly used in Internet of Things devices to minimize energy consumption [16–17]. Energy-efficient design principles like duty cycling and sleep modes are also employed to increase battery life. Additionally, as previously mentioned, advancements in energy harvesting technologies enable IoT sensors to be powered without the need for frequent battery replacements or grid connections [18–21].

1.1 Background Study

2 Aquaculture is the main source of aquatic animal food for human consumption and the industry with the greatest rate of growth in the world for producing animal feed. Because aqua farmed fish depend on water in an artificial tank for survival, feeding, development, and waste excretion, the water quality rapidly deteriorates, endangering the system's ability to grow and thrive. A high level of aquaculture success or failure is indicated by the quality of the water. Because it guarantees the health of every aquaculture system, water quality is therefore a crucial factor in fish monitoring activities. Fish development is encouraged and the incidence of fish diseases is reduced when water quality is kept within the ideal range [22]. Among the most important water parameters to monitor are temperature, water level, and pH. Water level, temperature, and potential hydrogen (pH) level are all crucial variables to keep an eye on and control. Fish breeders use manual testing to track the state of many water quality parameters. However, because water quality varies over time, manual testing is time-consuming and yields erroneous results. Consequently, cutting-

The monitoring system should use cutting-edge technology to solve this problem. Production closer to market demand, enhanced environmental standards and regulations, less catastrophic losses, less environmental management, reduced production costs, and better aquatic product quality are all advantages of mechanizing aquaculture settings. The system monitors and automatically adjusts the water's temperature, pH, and level. This system makes use of sensors, correction devices, and LoRaWAN (Long Range Wide Area Network) [23]. The micro-controller has pre-programmed threshold settings for the various water quality measurements. Water pumps and motors connected to microcontrollers are utilized to make makeshift correction tools. The pH level and water quality are stabilized through water replenishment. By doing this, the water can be brought to a temperature that is ideal for fish growth without exposing the fish to potentially harmful toxins. This technology is also more easier to use and significantly less costly for fish farmers. The sensors' data was only gathered once every day, or the user is alerted when a sensor trigger occurs. A specified time of day is chosen for data collection, and if the results fall outside of the range required for fish growth, the data is corrected.

1.2 Problem Statement

To keep an eye on everything, the fish farmers have to come to the farm multiple times a day. According to their schedule, employees visit the aqua farm frequently to check the water quality in the pond. While some people send a water sample to a laboratory for testing, others physically check the water parameters using a portable meter. Aquaculture is lagging behind other technological domains, like agriculture. Therefore, using technology to assist in resolving the issues is essential. Although farmers can personally inspect and determine the health status of the fish by manual monitoring, doing so on a regular basis will take a lot of time and effort. The water quality, which is crucial for a healthy fish, is the biggest concern for fish growers. Water level, temperature, and pH level are these three categories. When the water level in a pond or aquarium is too high, fish may flee, and when it is too low, they may suffer. Temperatures that are too hot or too cold can impair fish health, leading to fish skin diseases as Columnaris or even death. Fish health can be impacted by high pH levels, which can cause symptoms including frenzied swimming, lethargy, rapid breathing, or other abnormal behavior. The sickness known as hemorrhagic septicemia can ultimately lead to the fishes' death.[24–27] Fish are also harmed by low pH levels because they can develop TB. Producers must continuously assess these crucial elements in order to produce a healthy fish.

1.3 Objective

The study aims to integrate three sensors—temperature, water level, and pH level—with an Arduino microcontroller. The temperature sensor will be used to measure high and low water temperatures, activate the water pump to pump water into the tank through the first hose, and remove the existing water from the tank through the second hose when the temperature rises above 30°C. Additionally, the user will be alerted when the temperature falls below 25°C in the fish monitoring system. In addition, the project aims to use a pH level sensor to detect high and low pH values in the water and to activate the water pump to pump water into the tank through the first hose and to pump out the existing water through the second hose when the pH level in the fish monitoring system indicates a high value (above 9.0) or a low value (below 6.0). Additionally, the project will use a water level sensor to detect high and low water levels and to activate the water pump to pump water into the tank when the water level falls below the ideal level in the fish tank.

1.4 *Literature Review*

Keeping an eye on Smart Fish Farm Execution IoT reduces labor costs while increasing operational effectiveness and system application flexibility by using sensors and networks in place of more traditional methods. The gateway was approved for seamless operation in the monitoring system based on the actual use. In order to manage the fish farm and help the owner carry out scientific water quality monitoring, this approach uses remote intelligent monitoring [28]. The system developed and implemented an automated aquarium system to collect the data from every sensor. This technology was designed to keep an eye on and control the environmental factors necessary to satisfy a fish's optimal needs. installing a control module on an Internet of Things device, a service platform, and a mobile app to enable remote management of the water system. It is expected that farmers seeking to increase the production of high-quality fish in an effective fish farming system may find our technology to be a useful tool. These days, the farmers require technology that shows the current state of these variables in real time. When the water condition changes, even farmers don't know for sure [29–33]. Regular checks for these changes will be made by the proposed system, which will either act automatically or have the farmer act as though they are acting. A aspect of the system will be the ability to graphically display all of the streaming data from the fish monitoring system. Later on, a farmer might operate the machinery remotely using a smartphone. Aquaculture fish may now be fed automatically thanks to a smart aquarium gadget called Smart Aquarium Design. Using an Android-based Raspberry Pi, which was created to make changing the water and caring for fish in an aquarium easier [34]. Another study uses a predefined number of certain sensors at a predetermined period to automate a labor-saving and manual fish monitoring system [35]. Additionally, a remote monitoring system for aquaculture water quality utilizing the Internet of Things concept is presented in research in [36]. In the future, the entire farming system's sensors will be submerged in water as the data will be useful prior to harvest, and additional crucial sensors may be added based on the conditions.
A fish aquarium's intelligent automation control and monitoring system is developed. The Internet of Things technology used in the prototype allows fish keepers to remotely control the fish's water and food requirements at any time and from any location. The system has live streaming, an automatic water drain, and turbidity and temperature sensors.[37]. In addition, an automatic fish feeder is a machine that feeds fish automatically at a set time. Instead of feeding the fish by hand, it is possible to regulate the feeding activities in a certain way by utilizing a fish feeder that combines an electrical and mechanical system to create a device [38]. In a different study published in [25], the system is automated, reducing physical labor by keeping an eye on the fishes at a set time utilizing a certain number of sensors. Furthermore, one study aims to create a warm water energy thermal energy management system that can be used in Internet of Things (IoT)-based fish farming systems. Using Internet of Things technology, it created a smart fish farm's remote control and monitoring system [39]. A system for automating and monitoring fish farms is created. By utilizing Internet of Things technology, the prototype enables fish caretakers to alter the fish's needs (feed and water) at any time and from any location. The system includes a live broadcast, an automated water drain, and temperature and turbidity sensors [40]. The suggested approach facilitates real-time monitoring and control of a fish farming system through remote monitoring based on the Internet of Things (IOT). The system makes use of a variety of sensors in addition to the numerous sensors needed by the fish farming sector to maintain the wellbeing of water cultures.

2. Methodology

The three main sensors for this fish monitoring system are used in this project's methodology, along with an Arduino Uno. The Arduino software was used to pre-programme the Arduino Uno with instructions so that electronic components such as the temperature and pH sensors could operate. The sensors were used to measure the characteristics of the water quality. Customers were given access to the data after it was logged onto a smartphone using monitoring software. The system as a whole could circumnavigate the culture tank using this small prototype, which served as a floating platform. In this proposed IoT-based fishpond maintenance system, water level sensors are installed in the pond system to track the water level and water quality. The pond system has pH sensors placed to track the pH of the water. The pond's or fish farm's water temperature will be shown by the temperature sensor. The initial ideal value is encoded into each sensor to identify high and low levels and respond appropriately.[41]

2.1 *Level of Complexity*

Like many other things, fish have a tolerance range for specific environmental factors, and different fish farming practices require certain conditions to be met in order to be effective. Additionally, employees in fish farming ponds must be active throughout the workday in order to maintain a healthy habitat for the live fish. This article's main goal is to use distributed machine-to-machine communication to monitor and take action to maintain the sustainable ecosystem of fish species' habitats inside fishing ponds. As a result, some important operations will require less time. [42]. We provide a contribution to the improvement of an operational Internet of Things (IoT) system for fish farming system monitoring as part of this study. The Internet of Things system includes numerous sensors that measure critical water quality parameters including temperature, pH, and water level, as well as a small board computer that interprets data and transmits visual and auditory signals to the fish farm management. Data cannot be processed by the existing technology and made accessible to users through web or mobile platforms. If an extension module, like a modem, is used, end users will be able to monitor and control elements of the Internet of Things system for fish farming ponds in real time. This is one way to address the issue of fish farming ponds' remote location and need on clean fresh water. Another element that can contribute to the explanation of this project's complexity is the presence of four interconnected sensors that provide outputs to the system.[43] This should guarantee that the operation of the entire system is not impacted by the failure of a single sensor.

2.2 Tools and Procedure

- ***Hardware***

a. Arduino Uno

The Arduino Uno is a microcontroller with six analogue inputs and fourteen digital input/output ports. In addition to being powered by a computer via a USB connection, it can also be powered by an external power source, like a battery or an AC-to-DC adapter. The voltage supply needs to be between 7 and 12 volts in order for the board to operate correctly. The software that comes with Arduino can be used to program the Arduino Uno. The core language for Arduino software is C++, which is renowned for being easy for programmers to learn. The Windows operating system is compatible with this user-friendly application. Our choice of the Arduino Uno was influenced by the fact that it is less expensive than the Raspberry Pi. The Arduino software is more user-friendly than that of the Raspberry Pi. Furthermore, the software is made available as open-source tools, which greatly facilitates users' understanding of the platform's technical foundations. Open-source code created by professional programmers allows users to reduce the time they spend creating and troubleshooting their software.[44]

b. Water Level Sensor

A water level sensor can identify an unusually high or low water level in a stationary container. Based on the technique used to detect the liquid level, it is categorized as either a contact type or a non-contact type. The amount of liquid in the tank is determined by the submersible level sensor. The conductivity of the water increases with the amount of water the sensor is submerged in, lowering the resistance in the process. The conductivity of the sensor will decrease with decreasing water submersion, leading to a greater resistance [45].

c. Temperature Sensor

The suggested design makes use of a waterproof temperature sensor, the DS18B20. It is a digital temperature probe that is waterproof and won't break or leak when submerged in any liquid. Only one wire from the Arduino needs to be connected to the DS18B20 because it has a 1-Wire interface. The temperature probe can measure temperatures between -55 and 125 degrees Celsius, with an accuracy of 0.5 degrees Celsius. To determine the temperature, the output voltage of the sensor will be measured. The wire will be connected to the Arduino's analogue input pin since the sensor produces an analogue voltage [46].

d. PH Level Sensor

The pH sensor is one of the most important pieces of equipment to have when evaluating water. This kind of

Water and other liquids' alkalinity and acidity levels can be measured via a sensor. In order to ascertain the pH value of the liquid under examination, the aquarium hydroponic spare laboratory pH electrode probe BNC connector was the tool used. It can test the pH range in water from 0 to 14 over a temperature range of 0 to 60 degrees Celsius with an accuracy of 0.1 pH. Since the electrode probe is connected via a BNC connector, an Arduino board cannot be connected to a pH sensor circuit board. The pH sensor will be connected to the Arduino's analogue input pin since it produces an analogue output signal. [47]

e. Water Pump

The procedure of replacing the water in this system is essential to changing the overall quality of the water. An R385 DC12V Diaphragm Water Pump is used in this clever fish monitoring device. The pump draws air in and then releases it into the water, creating bubbles. The bubbles push out the water, causing it to churn and the carbon dioxide to rise to the top. When an external pump is submerged in water, a hose attached to the pump itself brings air to the pump[48].

f. 1Sheeld+

A framework called 1Sheeld+ makes it possible for Arduino to use smartphone sensors and capabilities in a wide range of Arduino applications. The 1Sheeld+ differs from the original version 1Sheeld in that it works with both iOS and Android smartphones, whereas the prior supported only Android devices. The simplest version of 1Sheeld+ consists of two parts. The physical board, which is the initial part, has a microcontroller and a Bluetooth module to transfer data between an Arduino and a smartphone. It may be powered and controlled by the same electrical supply that powers the Arduino Uno and is placed directly on top of the Arduino board. The second component consists of the mobile application that may be utilized on a smartphone and the software platform that goes with it. It enabled communication between the smartphone and the 1Sheeld+, which were both acting as virtual Arduino shields. [49]. The anticipated quantity of hardware required for the project is displayed in Table 1.

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)

Users can write code and upload it to an Arduino board using the open-source Arduino Software Integrated Development Environment (IDE). Because the Arduino IDE is an open source and expandable program, users can access a range of tutorials to better grasp the more technical parts of the software.

b. 1Sheeld App

Thanks to the software platform, 1Sheeld+ may use Bluetooth to link the Arduino to 1Sheeld's own apps that are installed on smartphones. You can choose from more than 40 different shields with 1Sheeld+. This system was constructed using a number of shields, including the "Data Logger Shield," "Email Shield," and "Push Button Shield." The 'Email Shield' is used to email the logged data to other users, the 'Data Logger Shield' is used to log data into the smartphone's memory, and the 'Push Button Shield' allows the user to choose when to begin logging the data.

2.3 Procedures

The project's technique is summed up in Figure 1. In order to have a rough idea of how to execute the project, the scope of research was chosen. To enhance and modify current monitoring system technology, journals and publications from various researchers were reviewed and compiled. A conceptual design was given following a review of the elements and features used in earlier research. An operational prototype of the system was designed.

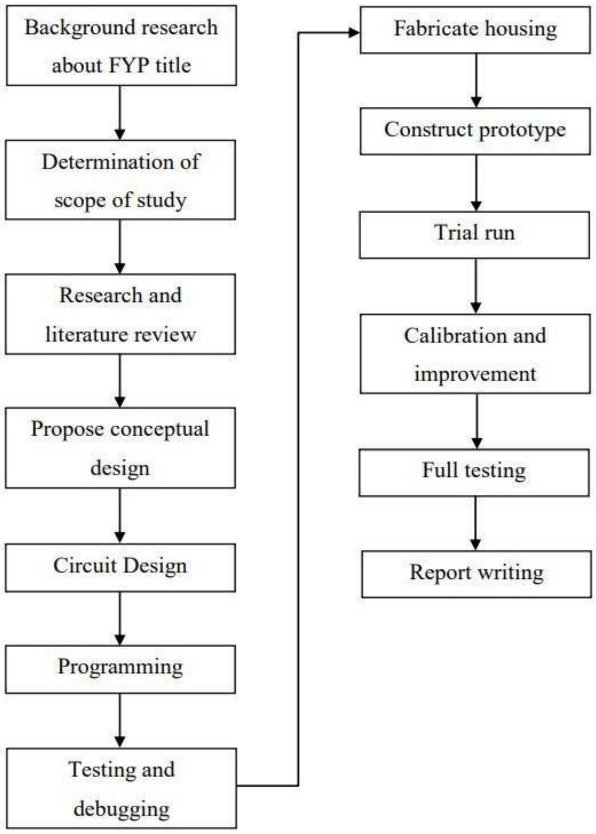

Fig. 1. Flowchart of the methodology

Initial Requirements /Background Research Design

Determining the number and kind of sensors had been part of the first project confirmation. Preliminary research and reference materials were then conducted in order to obtain additional project experience. Defined criteria include the project's start date, scope, work limitations, personnel and resource constraints, project environment, deliverables, and budget. Much research has been done in order to understand the project title.

- *Literature Review*

We looked into at least 30 papers and related links from previous work reviews and experts. In a research report, a literature review is crucial since it provides evidence to back up the project title and demonstrates that the system's history has been studied before. After screening each article, the key components were determined to be included in the project.

- *Proposed Conceptual Design*

A number of diagrams that together show the solution's strategy and operational flow are part of the project's basic design. A flowchart and block diagram are created to define the system. The project also includes planning for concepts, strategies, materials, and outputs over the course of its duration.

- *Prototype Development*

Color, images, packaging, and instructions were all incorporated into the model of the fish monitoring system to replicate its intended production process. A crucial step in the creation process is prototyping, which entails building a three-dimensional model of the idea. The circuit design will be created concurrently with the installation of the programming. The system will next go through testing and debugging before the external production process starts.

- *Testing*

Before starting development, it is crucial to test the prototype with real users in order to confirm design decisions. Early identification of possible problems and possibilities for improvement is the aim of the development process. After those problems and opportunities are fixed, you will be able to build a product that meets user needs and expectations. In addition to fixing issues that consumers encountered, this test run aids in the correction of errors. It can enhance how efficiently the system is utilized.

- *Operation*

The prototype should go back to the basic design to find and fix the issue if the system yields a bad outcome. Should the system react favorably, you can proceed to the final design and produce a decent model that looks acceptable. Before submitting the final design, a final test should always be conducted. A development project should aim to improve the economic and social circumstances of a group by producing a certain result. This process allows you to make additional adjustments. Additional ideas, creativity can be implemented during this process such as adding extra sensors.

- *Final Implementation*

The preliminary design drawings should be transformed into a comprehensive set of final design drawings (construction drawings) and project technical requirements during the final project design phase. Implementation is the process of converting plans and strategies into actions to accomplish previously stated strategic objectives and goals. The execution of the strategic plan is equally, if not more, crucial than the prior approach. It is significant that the system has accomplished each of the aforementioned goals.

2.4 Block Diagram

The water temperature, pH, and level between the tank wall and the water quality monitoring system were all measured by the temperature, pH, and water level sensors that were part of the suggested system. Between the tank wall and the water quality monitoring system, these sensors were utilized to measure the water's temperature, pH, and level. An Arduino Uno, which functioned as a CPU, gathered the sensor data. Since the Arduino Uno may accept an external source of any voltage between 6V and 20V, it was powered by a 9V battery pack. A 1Sheeld+ was positioned on top of the Arduino board and linked via Bluetooth to the 1Sheeld app in order to send data from the Arduino to a smartphone. [35] Data was taken and logged into the smartphone's memory using the 1Sheeld app. It was then sent to other users via email. The block diagram that can be viewed below shows the suggested structure. The block consists of two DC motors, an Arduino Uno, a 1Sheeld+, a temperature sensor, a pH sensor, and a water level sensor.

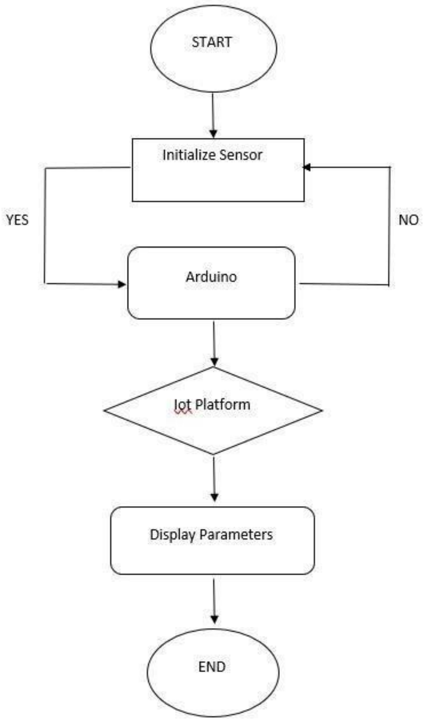

Fig. 2. Flowchart of the system

3. Results and Discussions

The Arduino Uno, which is infrequently used in Internet of Things applications, takes the role of the Raspberry Pi in this project. This is due to the fact that using multiple sensors on the Arduino will be more effective despite its complexity. Basic monitoring sensors like temperature, pH, and water level make up this system, but they have been coupled in an odd way to increase its usefulness quickly [50]. Additionally, this system performs several tasks by integrating multiple sensors into one. The suggested schematic design is shown in Figure 3 below, which also illustrates how the sensors were combined into a single system to gather all of the data from the monitoring systems and provide it to the user. The three parts of the system are data collecting, control, and optimization. Each member of this triad plays a distinct role in the overall system's functioning.

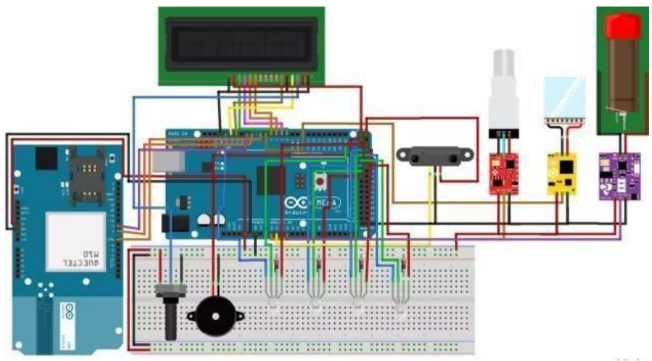

Fig. 3. Schematic design of the proposed system

As was previously said, fish farms use forecasting models and traditional methods and procedures to evaluate water quality concerns. All possibilities for eschewing conventional techniques and conserving labor time have been made available by this approach. The main objective of this system is to provide real-time monitoring with a fixed water level. It should be able to obtain precise readings and activate the water pump when the level falls or is needed [51]. However, when the readings get too low or high to replace the water in the tank, a pH level indicator should notify the user of the exact pH level in the water so that the user can balance or modify it and turn on the water pump. In the user application, the temperature sensor will always show the farm temperature in degrees Celsius, just like the pH level [52]. Figure 3 shows the example prototype of this fish monitoring system that uses the three main sensors. Prior to being integrated with numerous sensors, this prototype will undergo output testing.

The system prototype is depicted in Figure 4 below. Sensors are directly interfaced to the controller since the proposed system is designed to monitor the quality of household water. The sensor's properties, such as temperature, salinity, water level, and pH, are tracked by placing it inside the tank. The measured metrics can be shown using the Blynk application, which is loaded on devices to monitor water quality levels. This application is programmed on the same platform as an Arduino and requires a Wi-Fi connection to function.

(a)

(b)

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

All of the sensors should be able to read lice data and periodically alert users in accordance with the three objectives scheme. The reading collected at a specific moment is displayed in the findings below, and all of the sensors have been tested by adding false variables. Tables 1 and 2 display the results from the fish tank on two different days. All of the results were gathered three hours apart on each day. Table 1's results indicate that all four metrics remain unchanged, indicating optimal water quality. On the other hand, Table 2 shows that each of the elements has experienced minor changes throughout time. As a result, the water pump and sensors in the system are checked and turned on. The user-connected device receives periodic updates on all modifications and water quality levels.

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

When the water tank's state changes, the water pump is triggered, returning the water level to normal, as indicated in table 2. Because this water pump switch has two settings—manual and auto—it can be momentarily turned to auto in response to water level changes and manual in other situations. This is because the water level in a fish tank is an important factor. For fish to survive, the water level needs to be at the right level. To decide whether or not water has to be changed, the user may still consider other factors including pH, salinity, and temperature. The phone application created in figure 5 displays every ambient stimulus that is measured. In order to enable prompt action to support the fish livelihood in the fish farm, the application software may monitor temperature, water level, salinity, and pH level in real time and notify farmers of any irregularities.

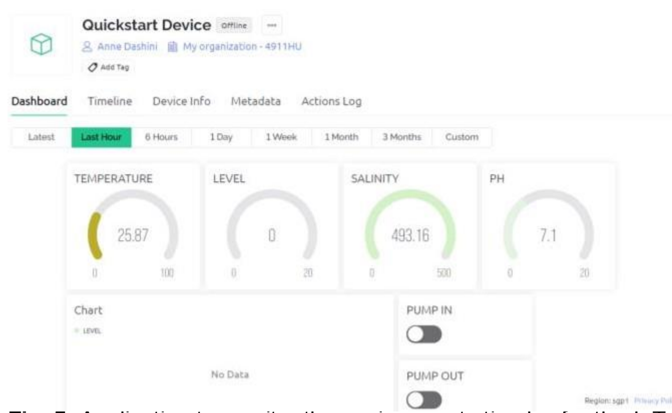

Fig. 5. Application to monitor the environment stimulus for the IoT Fish Monitoring System.

CONCLUSION

Any The growth of Internet of Things technologies can be applied to any sector. Among these is the integration of Internet of Things technology into fish monitoring systems. The combination of Internet of Things (IoT) technology and aquariums gave rise to the concept of a smart aquarium. An emerging and real idea for the field of contemporary fish care that combines aquaponics with internet of things technology is a fish monitoring system. It is very similar to this idea. An innovative microcontroller-based water quality measurement device has been successfully developed. [34]. As long as it was run continuously, the apparatus could cover the entire aquaculture tank. This allows measurements to be made at any point inside the tank. Numerous characteristics of the water in the aquaculture tank, including temperature and pH, may be measured by the monitoring system. It managed to escape away from the contaminated tank by moving independently. Under no circumstances will the system become stuck anywhere in the culture tank. Consequently, it is possible to measure the water quality attributes at different locations within the aquaculture tank. The microcontroller was an Arduino Uno, and a

1Sheeld+ was used to wirelessly transfer data between the Arduino and the smartphone over Bluetooth. The Arduino Uno was used to control the motor and sensors. Following the integration of the sensor system with the Internet of Things (IoT), users were able to receive updated data via email.

There is a chance that this fish monitoring method could be improved with further time and funding. One method to improve the system is to add more sensors, like water level transducers, dissolved oxygen sensors, and ammonia sensors [53]. The parameters should be checked in order to better monitor the health of the fish because the dissolved oxygen and ammonia levels in an aquaculture tank are equally important as the pH and temperature. The system can also be equipped with an Internet Protocol (IP) camera, which can be utilized for surveillance. An IP camera makes it possible for video recordings to be sent and received over the Internet and a computer network. Users of smartphones can watch in real time both the movement of the fish inside the aquaculture tank and the surroundings of the tank. Adding a Wi-Fi module to the system is another update proposal that may be used to build a system that continuously monitors the quality of the water. Through a customized software, users may view data in real time without physically placing their cellphones next to the system. Furthermore, it is highly advised that wireless sensors be used in order to make the wire connection process as simple as possible. One option to improve the device's capabilities is to replace the Arduino Uno with a PIC microcontroller, which is much smaller than an Arduino board. There is potential for the housing's proportions to be improved. The fish in the tank will be less easily intimidated by a moving object if it is smaller in size. Eco-friendly energy sources, such as solar electricity, can power the water quality monitoring system. Because AA batteries cannot be recycled, solar electricity would help minimize the amount of waste generated by electronic devices. Furthermore, changing the batteries on a regular basis is not required.

Through the creation of an Internet of Things (IoT) Fish Monitoring System, the combination of artificial intelligence, machine learning, and the Internet of Things (IoT) offers enormous promise for improving fish farming methods in future research. In order to monitor water quality indicators, forecast disease outbreaks, and optimize feeding schedules, future efforts could concentrate on improving predictive analytics models using machine learning algorithms [54].

Furthermore, more research into using AI-driven picture recognition technology can improve the evaluation of fish health and automate procedures for stock monitoring. Proactive management of fish farms can be made possible by integration with other IoT devices, such as sensors and actuators, which can enable real-time data collecting and automated reaction mechanisms [55–56]. All things considered, further study and application of these technologies have the potential to transform the fish farming sector, enhancing productivity, sustainability, and eventually, world food security.

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