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Web-Based Integration of IoT and Artificial Intelligence for Monitoring Aquariums

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***Abstract* – Technology is now an indispensable part of work across all fields and locations. For instance, in fish cultivation and among ornamental fish enthusiasts, technology plays a pivotal role in regulating and notifying when ornamental fish's environmental conditions require attention. This includes monitoring and alerting for cleaning or feeding needs. Ornamental fish are particularly sensitive, often carrying a higher price tag. Due to their susceptibility to stress and their relatively costly nature, those involved in ornamental fish cultivation and collection frequently face significant losses. These losses can occur when fish are collected, raised, and fall ill or, in the worst-case scenario, die. In response to these challenges, technological innovations have emerged to simplify the monitoring of ornamental fish's environmental conditions. This is achieved through IoT-based solutions accessible anytime and anywhere via the web. These innovations incorporate three primary sensors: pH sensors, clarity sensors, and temperature sensors. Additionally, Thingsboard is used to facilitate real-time monitoring of sensor data. These aquarium monitoring systems for ornamental fish hold the potential to enhance fish welfare and health, mitigate risks, and provide hobbyists and professionals with a more effective and informed experience in maintaining ornamental fish. However, it's important to note that the success of this system relies heavily on the quality of hardware, meticulous software development, and a profound understanding of the specific needs of ornamental fish.**

***Index Terms*—Automation, control, fishkeeping, sensor, thisngboard.**

I. Introduction

Traditionally, aquarium owners have had to manually check and adjust various parameters, such as water temperature, pH levels, ammonia levels, lighting, and more. This process can be time-consuming and challenging for owners with busy schedules [1]. However, with the advancement of technology, we can elevate our aquarium care experience by incorporating web-based "smart" components. This concept entails utilizing technology such as sensors, controllers, and internet connectivity to more efficiently and conveniently monitor, manage, and oversee aquarium conditions [2].

The traditional aquarium has long symbolized the captivating aquatic hobby. However, despite their allure, human interaction with underwater ecosystems in aquariums often presents a host of intricate challenges. Aquarium owners bear the recurring responsibility of monitoring and regulating various factors crucial to the well-being of fish and other aquatic organisms. These factors encompass maintaining an optimal water temperature, balancing pH levels, ensuring stable water clarity, and providing ideal lighting intensity. For individuals with demanding daily schedules, these tasks can evolve into time-consuming and distracting chores.

Yet, in today's digital age, we have an opportunity to revolutionize our engagement with aquariums. The innovative concept of web-based "smart" technology empowers us to attain a more interconnected and intuitive approach to aquarium care. By harnessing cutting-edge sensors capable of detecting subtle changes in the aquarium environment, coupled with automatic controllers enabling real-time parameter adjustments, and robust internet connectivity, smart aquariums enable us to monitor and manage critical aspects with unprecedented efficiency. Through a web-based platform, owners can remotely oversee the aquarium's condition and take necessary actions without physical proximity to the tank.

In contemporary times, technology is advancing rapidly, impacting various aspects of daily life. This development brings both advantages and disadvantages. One notable advantage is the ability of technology to remotely control aquarium functions, including feeding fish, as explored by Irawan. [3]. Research on the topic of Smart Aquariums has been previously conducted, as exemplified by Vishwas [4] in their study titled "Smart Aquarium Application based on Mobile and Short Message Service." This research focused on automating the process of feeding fish by programming an Arduino device to respond to SMS messages sent to a predefined phone number. Fatmawati conducted a study on this particular topic [5]. With the technology available today, the expansion and modification of features from previous studies, including automatic fish feeding via Android devices through the establishment of predetermined schedules, have been explored by Daut

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[6]. Muhardi conducted a study where automatic feeding has been designed, ensuring that users no longer need to worry about forgetting or being present during the feeding of their pet fish [7]. In addition to the previously mentioned advancements in automatic fish feeding, The research has taken the concept of smart aquariums a step further [8]. Not only does the technology facilitate automated fish feeding, but it also extends its capabilities to control the lighting within the aquarium. Controlling the lighting in an aquarium is a critical aspect of maintaining a healthy aquatic environment. Different species of fish and aquatic plants have specific light requirements for their growth and well-being. Additionally, controlling the lighting can help replicate natural day-night cycles, which is essential for the overall health and behavior of the aquarium's inhabitants. Tolentino's study likely involves the integration of smart technology, such as programmable LED lighting systems, with the aquarium setup. These systems can be remotely controlled or programmed to simulate natural lighting conditions throughout the day. For example, they can gradually brighten in the morning, reach peak intensity during midday, and then dim in the evening, mimicking the sun's natural path. Some advanced systems can even adjust the light spectrum to cater to specific needs, such as promoting plant growth or enhancing the colors of ornamental fish.

In the research conducted by Supomo[9], the role of the pond environment in aquaculture is of paramount importance for the sustainability of the cultivation process. Notably, it's not only the ponds themselves that matter; water quality also emerges as a pivotal factor influencing the success of fish harvesting. Supomo's research serves as a foundational source for other researchers conducting studies in this field. In the work carried out by Fauzi Amin [10], a system has been developed to monitor and control turbidity levels in shrimp pond water remotely through an IoT network. This innovative system enables the manipulation of actuators within the setup, specifically the water pump, to maintain stable water conditions and ensure optimal turbidity levels. The core of this system is the NodeMCU microcontroller, responsible for processing sensor data and transmitting it to the owner's smartphone. The Turbidity sensor is employed to measure water turbidity accurately. Pond owners can effortlessly manage this system, both automatically and manually, via a smartphone application.

The research studies mentioned earlier have provided valuable insights into the specific environmental conditions necessary for the maintenance and well-being of fish within an aquarium. These studies have involved a thorough and comprehensive analysis of the various factors and parameters that contribute to a healthy and thriving aquatic ecosystem within the confined space of an aquarium.

In essence, the research has delved into aspects such as water quality, temperature, pH levels, lighting conditions, and other crucial factors that directly impact the health and survival of the aquatic inhabitants. This analysis has been conducted with great precision and attention to detail, considering the specific needs of different fish species and aquatic life forms commonly kept in aquariums.

The significance of this research lies in its potential to lay the groundwork for a more advanced and sophisticated approach to aquarium management. By understanding the precise environmental requirements of the fish and aquatic organisms, the researchers are now equipped with valuable data that can be used as a blueprint for designing and implementing an innovative aquarium monitoring system.

This proposed system aims to leverage the power of cutting-edge technologies, such as the Internet of Things (IoT) and artificial intelligence (AI), to create a smart and automated solution for aquarium management. It will allow for real-time monitoring of critical parameters, automatic adjustments of environmental conditions, and even predictive capabilities to anticipate and prevent issues that could negatively impact the aquarium's ecosystem.

II. METHODS

In this study, the authors employed the Prototype Model research methodology, which involves the structured creation of the system under investigation. This approach was explored in-depth by Salim [11]. Abdullah's research explored the process of system development, which typically involves three key stages: gathering requirements, designing, and evaluating [12]. Irawan's study focused on the iterative nature of system development. If, in the final stage, it is determined that the created system is not perfect and contains flaws, the system undergoes a re-evaluation process, effectively returning to the beginning stages of development [13]. The stages in this prototype model are as follows:

A. Data Collection

Researchers collect data from the past, and this data plays an important role as a basis for the next stage of research. This data collection includes observations made at ornamental fish farming locations and the data obtained such as the ideal temperature needed for koi fish is at 8 to 30, the ideal pH is at 6.5 to 8 and the ideal clarity is at 1000 NTU. this allowing researchers to gather direct information about conditions and practices at those locations. In addition, they undertook an extensive review of previously conducted research, specifically focusing on studies exploring the factors that affect the health and well-being of ornamental fish.

By collecting this data, the researchers aim to build a strong foundation of knowledge and insight, which is important for making decisions and conducting in-depth analysis in the next stages of the research. This comprehensive data collection approach ensures that the research process is well informed and based on existing research findings in the field of ornamental fish farming. [14].

B. Prototyping

This design is carried out quickly and covers all aspects of the selected hardware starting from the sensors and microcontrollers to be used such as temperature sensors, pH sensors, clarity sensors, esp32, lcd and the rules used, the web dashboard interface design shown in the figure. This comprehensive design is the basis for making tools that aim to monitor the environmental conditions of the ornamental fish being studied by researchers [15].

The following is an example of the display of each sensor which will later be displayed in more detail through a tabular widget on the system test phase, the following is an example of the sensor display explained in the figure 1.

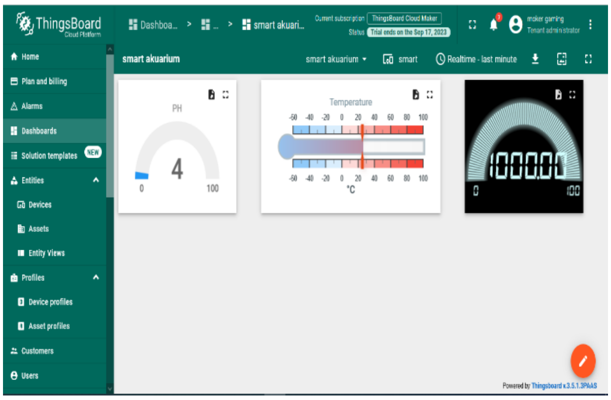

Fig 1.Widget Sensor

The image above is a widget for each sensor to accommodate the numbers generated directly from sensor readings which will later be displayed in more detail in a widget in the form of a table containing changes in sensor readings every minute which will be neatly displayed in detailed tabular form.

C. System Evaluation

Next, after the prototyping development stage, the researcher will determine the format and requirements of the entire device, identify all requirements, and outline the system to be created, starting from calibrating the sensor so that sensor readings comply with existing regulations, comparing sensor readings with tools to find out errors or usually called MSE with the formula used:

$$\left(\frac{1}{N}\right)\Sigma(y - y')^2 \qquad (1)$$

N is the amount of data, y is the original value and y' is the comparison value.

D. Encoding

At this stage the correct prototyping will be translated into programming in the form of the C programming language and using the rule:

```
IF(switch==HIGH)and(phval>=6            and
phval<=9)and(tssval<=1000)and(temperature
>=9 and tempval<=28)OR Switch=”LOW”
THEN Status = "No Action" On the contrary
Status = "There is Action"
END_IF.
```

This logical statement is used to test the status of a switch, which can be in two conditions: HIGH (ON) or LOW (OFF). The first condition checks whether the pH sensor value (phval) is within the range of 6 to 9, indicating suitable pH conditions. The second condition checks whether the Total Suspended Solids (TSS) sensor value (tssval) is less than or equal to 1000, signifying an appropriate level of suspended solids. The third condition verifies whether the temperature sensor value (temperature or tempval) is within the range of 9 to 28 degrees Celsius, indicating suitable temperature conditions. If any or all of the first through third conditions are met, then the "No Action" statement will be executed, indicating that no further action is required. However, if none of these conditions are met, and the switch is in the LOW state, the "There is Action" statement will be executed, indicating that action needs to be taken in this situation, such as turning off the device or taking other appropriate steps.

E. Device Testing

At the device testing stage, the coding that has been made before will be tested whether it can run properly or there are still parts that need to be repaired or there are still parts that are not as expected. So, sensor readings will be tested over a certain period of time to determine whether the sensor readings are in accordance with environmental conditions that have been conditioned, such as pH, and clarity is slightly affected in order to determine whether the sensor readings are correct or whether there are still errors, which will then calculate the level of accuracy or the level of errors that occur on the sensor.

F. Device Evaluation

Device evaluation is distinct from prototype evaluation; it involves assessing the entire completed device to determine whether it meets the desired specifications. If it doesn't meet the criteria, the device undergoes revisions, and the process returns to stages 4 and 5. When the system has been deemed satisfactory and has successfully passed the testing phase, the device is deemed ready for use.

III. IMPLEMENTATION

A. Prototype

The Wiring Diagram design applied in this study can be seen in Figure 2.

Mark	Tool
1	Ph Sensor
2	Temperature Sensor
3	Clarity Sensor
4	Esp32

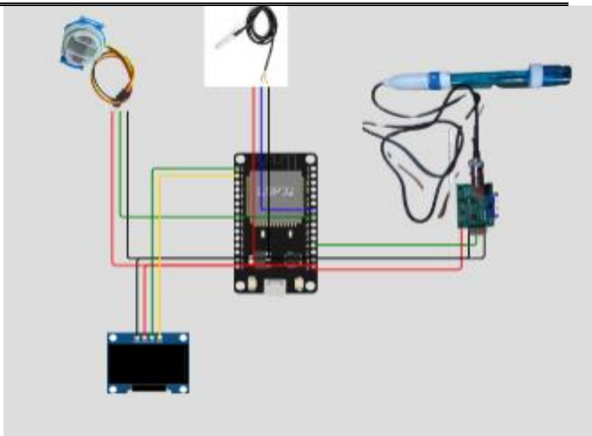

Fig 2.Wiring diagram

The following is the pin arrangement of each sensor that is connected to the ESP32 which corresponds to the number listed in Figure 4, which is connected via VCC, GND and these pins are in accordance with the source code that has been written on the ESP32 so that the sensor readings can be read and sent. to the thingsboard, there is also a picture of the thingsboard display in the picture 3.

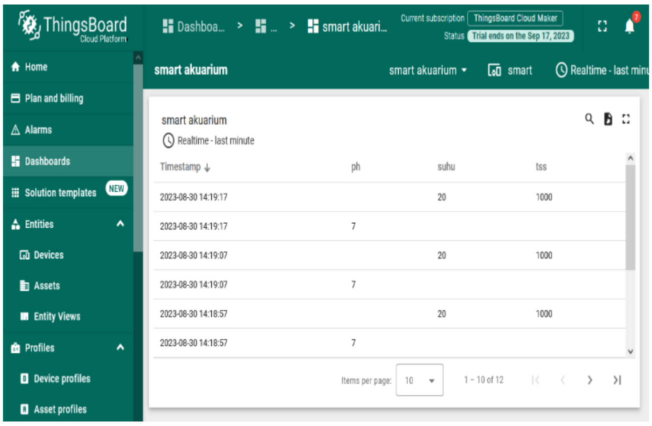

Fig 3. Thingsboard Display

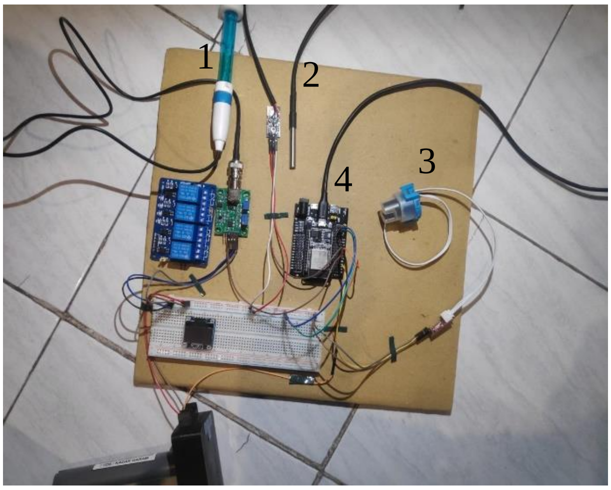

Fig 4. Design The Top View Tool

The image above is an image of a sensor that has been assembled with an ESP32 microcontroller with a pin arrangement that has been determined via source code so that the data reading from the sensor can be read properly by the ESP32.

From the image above the sensors have been marked with numbers on each sensor, the following is an explanation of the number marks on each sensor which have been arranged in table 1

Table 1. Tools

The pins of each sensor are described in table 2.

Table 2. Pinout Sensor

No	Component	Pin
1	ESP32	VCC,GND
2	Sensor pH	VCC, GND, 33
3	Sensor Suhu	VCC, GND, 27
4	Sensor TSS	VCC, GND, 34
5	LCD	VCC, GND, 12

So every sensor reading will be stored in the microcontroller which will later be sent to the thingsboard and displayed on the web dashboard that has been made on the thingsboard so that every minute sensor readings can be monitored anywhere and anytime so that the aquarium owner can find out when the aquarium needs maintenance or not.

B. Testing

There are also seven experiments that have been carried out to test sensor readings and test the connection between the microcontroller and the thingboard, which can be seen in Figure 4, and table 5. It can be seen that three trials have been carried out with different conditions on each sensor and are shown neatly and updated every minute on the web dashboard.

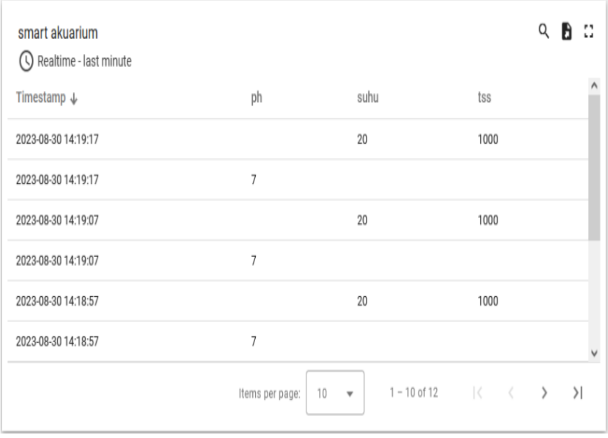

Fig 5. Dasboard Thingsboard

From Figure 5, a reading experiment was carried out from each sensor with each sensor reading, namely pH = 7, temperature = 20 and tss = 1000, the results of the sensor readings were as desired and displayed on a widget in the form of a table neatly and in detail on the web dashboard board. Thing that has been made.

Tabel 4. Calibration of Temperature Sensor

Name	Temperature Sensor	Termometer	Delta
Experiment 1	27	27.5	0.5
Experiment 2	29	30.6	1.6
Experiment 3	-	-	-
Average	28	29	1.05

Tabel 5. Calibration of pH Sensor

Name	pH sensor	pH meter	Delta
Experiment 1	4	4.16	0.16
Experiment 2	7	7	-
Experiment 3	5	6.16	1.16
Average	5,3	5,8	0.66

So figure 5 is the result of the advanced implementation of the previous widget which was neatly arranged so that the aquarium owner doesn't experience confusion with the sensor reading results, Table 3 is the trial results that have been summarized in the table.

Table 3. Test Result

No.Test Result	Temperature	pH	Tss	Action Result	Validation
1	20ºC	7	1000	True	Valid
2	25 ºC	6	1100	True	Valid
3	30 ºC	8	1050	True	Valid
4	25 ºC	5	900	True	Valid
5	28 ºC	7	950	True	Valid
6	28 ºC	9	1000	True	Valid
7	25 ºC	4	1000	True	Valid

Starting from Figure 4 to table 3 is three different tests have been carried out, each facing different conditions on each sensor. The results are displayed in a neat display and updated every minute on the web dashboard.

Results of the sensor readings are as desired and displayed neatly on the web dashboard of the thingsboard that has been made.

C. Calibration Sensor

Calibration is a series of activities that establishes a relationship between the value indicated by a measuring instrument or measurement system, or the value represented by the measuring material, with known values related to the quantity measured under certain conditions [16].In previous studies, generally only comparing measurement data from sensors with measuring instruments that have been calibrated from the factory [17], from these conditions, calibration is only carried out with the aim of resetting the initial value only. While the decrease in sensor response due to changing conditions, time and in line with the frequency of use will cause the output value to be read to change and may no longer show the true value. In such conditions, the measuring instrument must be recalibrated.

From three trials of the temperature sensor and calculating tool, the difference was 1.05

From three trials of the pH sensor and calculating tool, the difference was 0.66. From the results of the average value above is used to calculate the average error value.

D. MSE

MSE stands for "Mean Squared Error". It is one of the commonly used metrics to measure the error rate or difference between predicted values and actual values in the context of regression analysis and statistical modeling. MSE calculates the average of the squared difference between the predicted value (y') and the true value (y) of a number of data. With N as the number of data, the MSE formula is as follows:

pH =

$$\left(\frac{1}{3}\right)\left((0.16)^2 + 0^2 + (1.16)^2\right) = \left(\frac{1}{3}\right)1.35 = 0.44 \quad (2)$$

Temperature =

$$\left(\frac{1}{3}\right)\left((0.5^2 + 1.6^2 + 0^2)\right) = \left(\frac{1}{3}\right)2.81 = 0.94 \quad (3)$$

So from the calculation above it can be concluded that the error value of the pH sensor is 0.44 and the error value of the temperature sensor is 0.94.

IV. COCLUSION

Aquarium monitoring systems designed specifically for the aquarium hobbyist not only offer great promise in improving the overall well-being and health of the aquatic creatures in them, but also present great opportunities in mitigating the potential risks that can arise in complex aquarium ecosystems. In addition, the system is able to provide a more robust and in-depth informed maintenance experience, both for the hobbyist just starting their journey in this world and for the seasoned expert who is always on the lookout for innovation.

However, it should not be forgotten that the efficacy of such systems is highly dependent on utilizing the best hardware available on the market, including the latest technology and high-quality devices that can ensure the smooth operation of the system. In addition, software development must be carried out carefully and thoroughly to achieve a level of excellence that allows the system to present accurate and useful data for users. All of these elements must be supported by a very deep understanding of the various requirements and preferences of ornamental fish which can be very complex and varied, covering aspects such as temperature, water pH, water quality and appropriate nutrition.

In doing so, the success of such an aquarium monitoring system will be increasingly respected and relied upon by the ornamental fish enthusiast community worldwide, as they will have greater access to the information necessary to care for and develop their aquariums in a better and more sustainable way.

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