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Water Quality Monitoring for Goldfish Aquarium using IoT

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Abstract: ***The goldfish is awell-known beautyful aquariumfish, butit is highly sensitive to the environment; thus, it demands lots ofcare and attention from the owner. The main purpose of this project is to assist the goldfish owners to monitor the pH level, turbidity and temperature using the Internet of Things (IoT). A productis developed based on the user-centric requirements, and the Design Thinking Model in five major phases of actions, namely empathise, define, ideate, prototype, and test. Controlled by acircuit board of Arduino WeMos D1 R32,the electronic device usesthree sensorsto monitor the conditions of the water--pH, temperature and turbidity. Testing of thefunctionalities was performed successfully and yielded meaningful results. The input and output functions operated smoothlyaccording to the flow chart,and were indicated by LED;at the same time, notifications were sent to the Blynk application platform.The LCD screen displayed the real-time conditions of water quality in the aquarium;the data were used to maintain the ideal conditions of the water for the goldfish to live in.***

Keywords*: Water quality, goldfish, IoT, design thinking.*

I. INTRODUCTION

According to Hodgson, Barton & Darling [1], living with pets and treating them like our own family members havebenefitsto the human health.Pets function as a social capital builder and harm reduction agent;provide motivation for developing healthy behaviours and potential therapies for treating patients. Studies show that animals play an important role in reducing anxiety, stress and depression [2];this is especially true for pets that live in the watersuch as ornamental fish, which are good for mind therapy and spiritual treatment. In addition, interacting with creatures in aquariums is one of the therapies that brings humans closer to the nature [3]. The keeping of ornamentalfish hasbecome an increasingly important aspect of life today worldwide. Ornamentalfish are often referred to as living gems due to their gorgeous colours, beautiful body shapes and carefree behaviours that appeal to anyone who looks atthem [4]. One particular interesting species of ornamental fish is the goldfish or CarassiusAuratus,the scientific name.

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It is a very popular species favoured by the ornamental fish enthusiasts because of its attractive species diversity,with a wide range of body shapes and colours;moreover,the fish has high environmental tolerance [5]. Fish pond owners and ornamental fish enthusiasts of goldfishshould frequently monitorthe water quality. This is because goldfish are extremelysensitive to water quality. Goldfish breeders face many difficulties because the survival rate of goldfish fries

is low [6]. Water quality monitoring should be done regularly to ensureadequate suppliesof water and oxygen. Human neglect in monitoring the fry development and quality of aquarium water is one of the causes of goldfish deaths. The chlorine content in the water can cause the aquarium water to become polluted and cloudy; urine and ammonia from the fish cause high turbidity, increasing the pH level and temperatureof the water. With the sophisticated and advanced technology, the water quality can be monitored such that the oxygen, water pH,and turbidity arepreserved at the best levels, providing a safe environment for the goldfish in the aquarium.

II. RELATED WORK

Goldfish require a great deal of care as they are very sensitive to the water quality, and die easily dueto adverse changes in the environment. According to [6], goldfish live comfortably in these conditions: temperature of 28°C, pH level of 7.9, dissolved oxygen of 3.4mg per litre, alkaline amount of 183.93mg per litre, ammonia content of 51.92µg per litre, and turbidity value of 23.3cm. Goldfish owners must consistently monitor these parameters to prevent them from suffocating in extreme water conditions. Theyneed to spend time to do these chores frequently:changing thewater or filteringthe water, cleaning the aquarium, and performing water treatment using the anti-chlorine and anti-fungus processes. If the owners have a hectic and busy work schedule, they mayneglect caringfor the goldfish, which will havea negative impact on the goldfish's health [7].

After exploring the characteristics of various current products in the literature, three of them areavailable in the market. The first product is Horiba W-23XD Water Quality Monitoring System [8],which is used to measure pH values, dissolved oxygen, soluble solids, temperature, turbidity, depth and potential of oxygen reduction. It is widely used in the water treatment processes for sewage water plants, lakes and marshes, dams, farms and nurseries. This product is meant forbig-scale water treatment purposes,and is not suitable for monitoring the water conditions of a home ordomestic aquarium.

The second product is SmarTROLL Multi-Parameter Probe manufactured by Nilsen, Nielsen &Næss[9]. It is used to measure pH values, water levels, resistance, density, temperature and biometric pressure. This product can transmit data via Bluetooth to the user'sapplication.Quite similar to the first product, this product is also meant for large-scale water treatment processes such as those of fish pond, groundwater, mining and water surface. The third product is Dr5000 Multi-Parameter Water Analyser for Water Treatment or Fish Farm [10]. It is used to measure temperature,

pH values, dissolved oxygen values, insulation, turbidity and chlorine content. It is usually used for water treatment processes such as that ofthe fish pond, and hence not suitable for domestic aquariums. There is a need for a small-medium size product that meetsthe users' requirements ofhome aquariums dedicated to goldfish rearing. The objectives of this study are as below:

i. To design a prototype deviceformonitoring the water quality of the goldfish aquarium according to the users' needs.
ii. To develop a prototype device for monitoring the water quality of the goldfish aquarium based on the design thinking model.
iii. To test the validity of the prototype deviceand its functionalities in monitoring the water quality of the goldfish aquarium using the IoT.

III. METHODOLOGY

The Design Thinking Model is adopted in this studyto guide the development process. It consists of five main phases of actions,namely empathise, define, ideate, prototype, and test.

a. Phase 1: Empathy

Empathy is a process to identify and statethe problems related to the death of the goldfish. In this case, three goldfish owners were interviewed so that the researchers can obtain the relevant information and understand the problems. The questions were based on 5 Whys about themortality rate of the goldfish.

The analysis of the interview data yielded five problem statements: first, Goldfish dies easily; second, Goldfish is sensitive to its environment; third, it is difficult to monitor the water quality of an aquarium; fourth, it is difficult to change the water in an aquarium; fifth, it is difficult to monitor the pH value, oxygen content and turbidity of the water in an aquarium. The interview data aresummarised and illustrated in Figure 1.

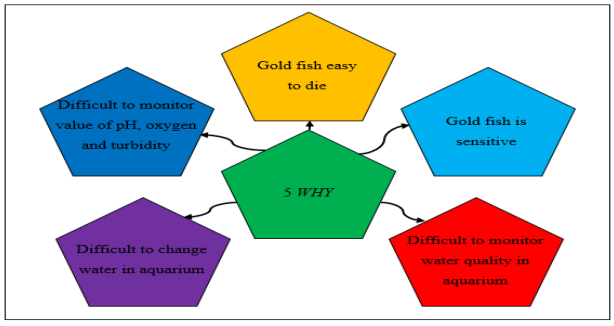

Figure 1. The users'answers to5 Whys

There are three parameters that aredifficult to monitor, namelythe pHvalue, oxygen content and turbidity of the water. Based on the five problem statements,the researchersare able to formulate realistic objectives and come up with a plan for developinga prototype device that can monitor thewater quality ofthe goldfish aquarium using theIoT.

b. Phase 2: Define

As the water is contaminated, the oxygen content in the water decreasesas the state of pH that becomes acidic or alkaline. According to Li [11], goldfish will be exposed to the Spring Viraemia of Carp viruses when the water temperature is too high or too low. Under unusual or extreme water temperatures, goldfish are susceptibleto diseases associated with brain tissues[12]. The goldfish will die as the conditions of the aquarium water do not meet thoserequired by the goldfish to live. Problem analysis was carried out and the user requirements were identified using the 5W1H technique. Through this technique, the researchershave clearer ideas about the product features and characteristics required by the consumer. Table 1 shows the use of 5W1H technique in the development of this prototype device.

Table 1. Using the 5W1H technique to propose a solution

What	What is the problem of monitoring water quality for the goldfish?
Who	Who are responsible for monitoring the conditions of the goldfish in the aquarium?
Where	Where, on the scales,are the optimum values of pH, temperature and turbidity for the goldfish in the aquarium?
When	When will the conditions causethe goldfish to die?
Why	Why does the water in the aquarium become polluted?
How	How to usethe pH, temperature and turbidity sensors to monitor the water quality such that the goldfish will live in the aquarium?

c. Phase 3: Ideate

In this phase, the flow of the system is designed, after considering the inputs from the sensors and the expected output. The description of the prototype device for monitoring the water quality of the goldfish aquarium consists of three main sections:the circuitry hardware, the software, and the project overview. Several aspects of the consumer needs are taken into consideration such as safety, functionality and usability. The flow of the operations is indicated in Figure 2. The schematic and circuit overview are presented in Figures 3 and 4.

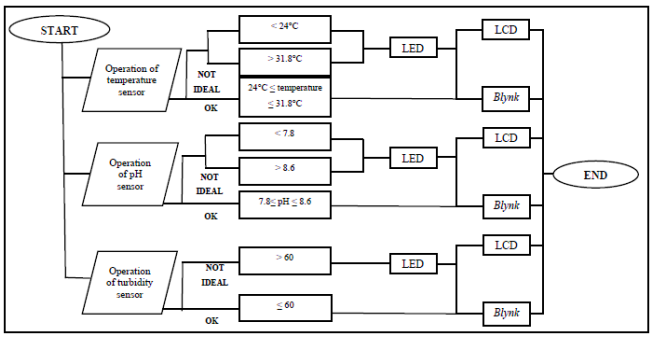

Fig. 2: Flow chart of prototype device formonitoring water quality of the goldfish aquarium using IoT.

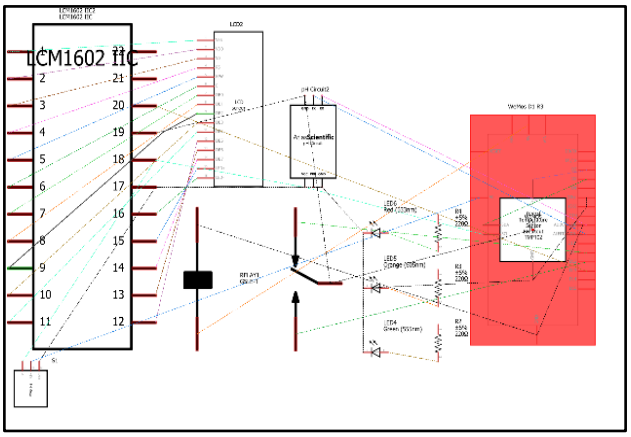

Fig 3: Schematic circuit of prototype device formonitoring water quality of the goldfish aquarium using IoT.

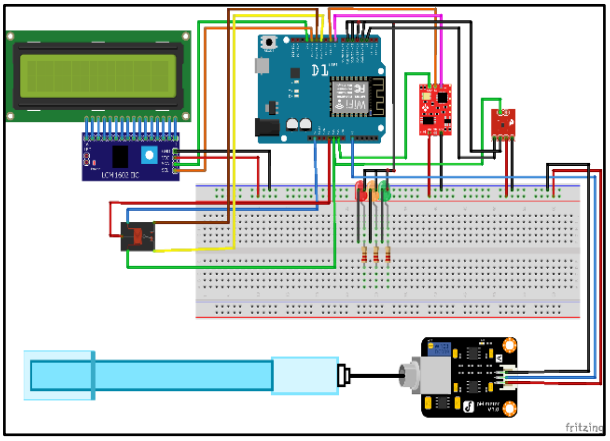

Fig. 4: Circuit overview of prototype device formonitoring water quality of the goldfish aquarium using IoT.

d. Phase 4: Prototype

In this phase, theactual prototype deviceis produced.The development of the prototype deviceis divided into three stages:assembling the circuit board, software programming, and casing construction. The main task is to perform coding and integrate all the components into a complete system so that the developed prototype device can perform all the intended functions;through the control ofArduino WeMos D1 R32, the device can receiveinput data from the pH sensor, temperature sensor, and turbidity sensor, and display the output through the LCD and LED. The development of the programming software focuses on the input of the pH, temperature and turbidity sensors,each of which detects the actual value of its related parameter. The outputs of the programming software are displayed on the LCD and LED,which havebeen linked to and programmed on the cloud pushing box to send the information to the Blynk application. Lastly, the process of casing development was carried out byarrangingand placingthe circuit components in ajunction box.

e. Phase 5: Testing

The prototype device is now fully developed but its functionalities and usability need to be tested and evaluated before it can be put into service.The testing of the device was conducted using two methods, namely the components and user acceptance tests. Each unit of the device underwent the circuit development, usability, and safety tests. The sensor modules are combined to form a complete circuit connected to Arduino WeMos D1 R32 in order to achieve the objectives and goals of the project. Testing was also carried out to ensure that the circuit functions properly as planned. The testing was validated by three experts:the first was an officer from the Fisheries Department of Malaysia;the second and third were product development experts from higher education institutions.

The pH sensor testswereperformed under three different conditions. When the pHof the water turns acidic, the green LED lights up,indicatinga dangerous pH condition. The LCD displays the pH value of the aquarium water. Blynk notifications are sent tothe smartphones. When the pHof the water turns alkaline, the green LEDs turn on,indicatinga dangerouspH condition. The LCD displays the pH value of the aquarium water. Blynk notifications are sent to thesmartphones. When the pHof the water is ideal, the LCD displaysthe good pH reading values. The green LED does not turn on and the Blynk display indicates that it is safe (Figure 5).

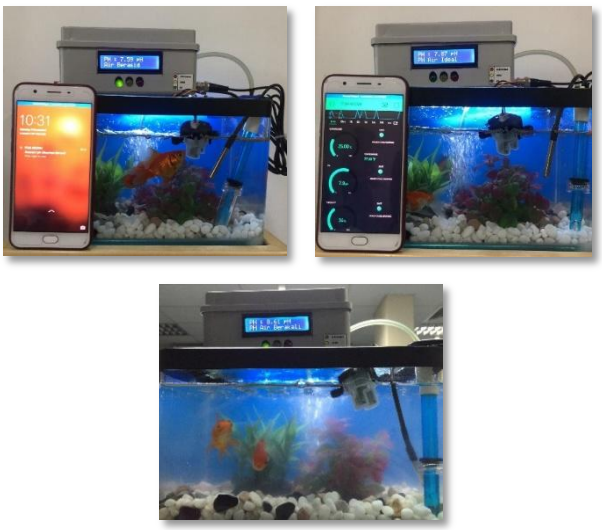

Figure 5. Testing of the pH sensor

The temperature sensor tests were performed at low, ideal and high temperature conditions. The ideal temperature test was done in the morning around 10am to 11am. The LCD and Blynk applications display good temperatures.

The low temperature test was done at night around 10pm. The water temperature is low at night asit is influenced by the temperature of the environment. The LCD screen displays the aquarium water temperature values. When the yellow LED is on, the Blynkscreen displays an unsafe temperature notification.

The high temperature test was conducted in the afternoon at 1 to 3 pm. The temperature was found to be rising. The LCD and Blynk applications display the temperature reading values. Yellow LEDs indicate that the temperatures are dangerous for the goldfish (Figure 6).

Figure 6. Testingof thetemperature sensor

The turbidity tests were conducted for 7 days. There were changes in the percentage of turbidity of the aquarium water from the first day to the seventh day. When the turbidity value is more than 60%, the LCDs and Blynk applications display the percentage values of the aquarium turbidity readings. If the red LED lights up,it is a warning signal that the water condition isdangerous. Meanwhile, whenthe water turbidity is at a safe level, the LCDs and Blynk applications show the percentage readings of turbidity. The LED does not turn on because the water turbidity is at a safe level (Figure 7).

Figure 7. Testing of the turbidity sensor

IV. RESULTS AND DISCUSSION

The first testing process was carried out after the completion of the development phase;the output and input of each sensor of the prototype device were tested. The functionality test was carried out using appropriate tools and equipment. The testswere conducted in a period of 1 week in three different situations. The tests were carried outinthe morning, evening and at night. The test results for each sensor wererecorded.

Theanalyses of the 7-day test results show that there were changes in the pH value of the aquarium water from day one to day seven. The water pH increases over time as a result of the impurities generated by thegoldfish. Moss or dirt on the rock is also a factor thatchanges the pH value of the water. The pH of the water turns alkaline when the limestone rocks in the aquarium are not washed and cleaned(Table 2).

Table 2. Results of testing the pH

Day	Time/LED					
	Morning	LED	Evening	LED	Night	LED
1	7.73	×	7.75	×	7.78	×
2	7.85	×	7.90	×	7.97	×
3	8.02	×	8.08	×	8.14	×
4	8.19.	×	8.25	×	8.31	×
5	8.37	×	8.43	×	8.49	×
6	8.55	×	8.61	✓	8.68	✓
7	8.71	✓	8.74	✓	8.77	✓

Based on theanalyses of the 7-day test results, the researchers found that the environmental factors affect the water temperature of the goldfish aquarium. The water temperature at night is lower than that of the morning and noon. The analysis shows that the temperature varies over time,and the highest temperature is at noon. When the water temperature is high, the goldfish moveactively because of discomfort or stress caused by the heat. At high temperatures,the goldfish are susceptible to diseases such as the Spring Viraemia of Carp (Table 3).

Table 3. Testing of functionality based on temperature

Day	Time/LED					
	Morning	LED	Evening	LED	Night	LED
1	27.0°C	×	34.5°C	✓	22.5°C	✓
2	28.0°C	×	30.5°C	×	23.0°C	✓
3	26.5°C	×	31.0°C	×	22.0°C	✓
4	29.5°C	×	36.5°C	✓	26.0°C	×
5	27.0°C	×	31.5°C	×	26.0°C	×
6	28.0°C	×	29.5°C	×	24.0°C	×
7	25.0°C	×	30.0°C	×	23.0°C	✓

An analysis was carried out on the7-day test results of water quality without using a water filter. Based on the analysis performed, the researchers found that the water was cloudy from the first day to the seventh. Changes in the water turbidity occur as a result of the dirt and impurities produced by the goldfish. The cloudy water reduces the oxygen content in the aquarium; the goldfish areforced to swim to the region near the water surface to take in oxygen from the outside (Table 4).

Table 4. Testing ofturbidity over 7 days

Day	Time/LED					
	Morning	LED	Evening	LED	Night	LED
1	15%	×	20%	×	22%	×
2	30%	×	35%	×	38%	×
3	40%	×	43%	×	47%	×
4	50%	×	54%	×	58%	×
5	62%	✓	68%	✓	70%	✓
6	74%	✓	77%	✓	80%	✓
7	82%	✓	86%	✓	90%	✓

Expert validation had been done in order to test the usability of the prototype device for the users. Selection of theexpertsis based on the expertise and experience in the field of electric and electronics engineering.

The developer performed an analysis based on the feedback or answers given by the specialists selected. Each expert's validation is divided into three parts, which are design, functionality and commercial potential. Based on the validation results, this product achieved good average scores for all the parts mentioned above.

There are some comments and proposals for improving the prototype device. The first expert validation is given by a fishery officer. The expert mentioned that the prototype device developed isa suitable tool formonitoring water quality.It is an easy-to-useideal instrument for ornamental fish breeders who can use itto monitor the quality of aquarium water and maintainit at a satisfactory level. Improvements can be made by adding buzzers to provide warning signals. Another expert from the product development area, commented that the detector works well, and suggestedthat improvements need to be made by providing a user manual as the prototype deviceislinkedto theIoT. The expert said thatthe prototype device works well and can be further improved by using a buzzer as an alarm when the water is turbid.

The prototype device has been successfully built; it is definitely a useful tool in the hands of the goldfish aquarium owners. Secondly, the sensitivity of the detector was analysed. Next, tests were successfully conducted on the feasibility of the prototype device in monitoring the water quality of the goldfish aquarium using the IoT. The Blynk application was successfully used and accessible by up to five (5) smart phones.

The findings show that the prototype device is really helpful and useful for the users. It has potential commercial values because the functions and features of the device meet the needs of the user.

V. CONCLUSION

Overall, the researchers noted that the development of theprototype devicemonitoring the water quality of the goldfish aquarium using IoT has been successful;the device can be used to monitor the temperature, pH and turbidity of the aquarium water according to user requirements.

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