An IoT-Based Smart Aquarium Monitoring System

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***Abstract*— Fish is one of the pets that need intensive care compared to others pet like cat, rabbit and hamster since they live in the water. Usually, fish had been abandoned with lack of care such as unclean water in the aquarium or fish breeding ponds. An IoT-based smart aquarium monitoring system is one of the solutions to cater the problems. This research presents a developed prototype of an IoT-based Smart Aquarium Monitoring System to keep a fresh water in the aquarium for fish life habitats. The system functions to monitor the fresh water for healthier fish life habitat. This system operates as fish feedings system and controlled by a smartphone in its operation. Arduino MEGA and NodeMCU controllers are used in the designed system. Wi-Fi communication on the NodeMCU is used between the smartphone and the controller to control the operation. Analog pH sensor is used to detect the pH value of water and display the value through the Liquid Crystal Display (LCD). The coding is created by using Arduino Software IDE while the BLYNK software used to create software applications for the Android operating system. The system is designed to monitor the pH value that is suitable with the type of fish life and control the fish feeding using smartphone in android application. This research is significant towards IR4.0 system development in supporting fish pets and larger project for fish breeding in the pond can be sampled with this project that contributes to economy impacts for the country.**

***Keywords*—** *Internet of Things (IoT), Smart Aquarium, pH water monitoring, fish feeders, pH Sensor*

I. INTRODUCTION

Since the dawn of time, people usually have their own pet as life companion. Fish is one of pets that live in water that people typically had not only as life companion, but as mental therapy and as house decoration. Even though, it is normal the fish can be abandoned by the owner as the maintenance is a bit complex compared to another animal like cat and dog. Hence, there are two important aspects for fish which are the water quality and enough daily feeding. An IoT-based Smart Aquarium Monitoring System has been designed to inspire people to take care of their pet (fish) easily and lovingly. The features of this smart aquarium help people to treat their fish perfectly. The pH value indicator by LCD display makes the user understand the cycle of the water replacement that need for their fish aquarium. This pH indicator also helps people to determine the value either for freshwater fish or saltwater fish. The IoT feature through Wi-Fi module can be controlled by user using smartphone as they want to feed the fish at anytime and anywhere.

A. Internet of Things (IoT)

Based on authors in [1], the Internet of Things (IoT) is one of the field study that has advantages of Wireless Sensor and Actuator Networks (WSAN) and Pervasive Computing domains. The security challenges are rooted in the technology and how information is acquired and manipulated by this technology [2]. IoT is very important to face a problem in accessibility in both physical and environments every day. The IoT offers a method for potentially removing these obstructions [3]. IoT holds promise benefits to emerging and developing economies such as in sustainable agriculture, water quality and usage, healthcare, industrialization, and environmental management [4]. ITU (International Telecommunication Union), proved the main vision of IoT, where an environment things are able to talk while their data can be processed by machines to do desired tasks [5]. Enabling technologies for the IoT can be divided into three categories which are technologies that enable "things" to get the information, to process information and technologies to improve security and privacy [6].

Many challenges faced to make IoT as stated from research in [7], if devices from different manufacturers do not use the same standards, interoperability will be more difficult, requiring extra gateways to translate from one standard to another. The implementation of an IoT application requires the integration of a range of information and communication technologies in the form of hardware and software [8]. For information that will be created, should have the capacity to reach some generalizable conclusion from the interpreted sensor information [9]. In terms of investment, IoT has mostly been in the development of software for smart homes and buildings by private investor [10].

B. pH for Water Health

Regarding research in [11], for establishing water quality criteria on fisheries, the acidity or alkalinity of the water is an important factor to be considered support for a good fishery. The same of the impacts of the pH and carbon IV oxide (CO2) strain on the oxygen-conveying limit of the blood has additionally been noted [12][13]. A major reason for adapting new tank inhabitants carefully is the possible difference in pH-value of the transported water and the tank [14]. The changes in the pH, especially for sudden changes, can prove that it is harmful or even fatal to fish. Amongst the species of fish, breeding occurs only within a specific pH range [15].

By referring [16], acid deposition has aroused concern about aquatic organisms in soft water lakes and streams, as the loss of indigenous species is usually observed once hydrogen ion concentration decreases. As stated by [17], it should be noted that different life stages of an amphibian might additionally have different needs. Aquatic systems are exceedingly vulnerable because of their tendency to accumulate moderately high concentrations of chemicals entering from variety of point and non-point to its water bodies [18][19]. In term of saltwater for fishery, a steady marine aquarium requires more gear than freshwater frameworks, and requires more stringent water quality observing [20]. For saltwater fish in aquarium, the pH of saltwater should never be less than 8.1. Correction of deficiency is needed so that the level is between 8.1 to 8.3 and suggested not to change pH by more than 0.5 per day to limit stress on aquatic inhabitants [21][22]. pH sensor used to

read the pH value of the water. Based on research in [23], a combination of pH electrode, the most widely used variety, there are actually two electrodes in one body. One portion is called the measuring electrode, the other is the reference electrode.

II. RELATED WORKS

Table I shows the list of previous projects that related to an IoT-based Smart Aquarium Monitoring System.

TABLE 1: The list of previous projects [24], [25], [26], [27] and [28]

Project	Feature	IoT	pH	Advantage	Disadvantage
Aquarium Auto Refill with Arduino [24]	Pumping station to refill a reservoir	No	No	Auto refill water	Need user to feed and monitor the water quality
Aquarium Temperature Monitor [25]	Manages its own temperature	No	No	Maintains the aquarium temperature	Need user to feed and monitor the water quality
IoT Aquarium Light Controller [26]	Better handle artificial light activation	Yes	No	Light management by android user	Just good for decoration
Automatic Fish Feeder [27]	Full automated fish feeding schedule	No	No	Auto fish feeding	User need to monitor the water quality
pH Level Monitor [28]	Display the PH level of a certain substance	No	Yes	Can be used to monitor the acidity of aquarium or pond	Need user to feed the fish

Usually, smart aquarium invention focuses on feeding, as it is the most important for fish, for that the fish do not die because of starvation. Other than that, certain smart aquarium invention used to be as monitoring system, such as temperature and pH level indicator. Every project has its own features, advantages and disadvantages. This proved that an IoT-based Smart Aquarium Monitoring System is the best solution to improve the existing project.

III. RESEARCH METHOD

In hardware implementation, the project utilised an Arduino MEGA and NodeMCU as a microcontroller. For actuator, a servo motor (sg90) used as fish feeder mechanism. There is only one sensor used in this project, which is pH sensor (SKU: SEN0161) to detect the level of pH water. The 16x2 LCD display used as an indicator that indicates the level on pH water in the aquarium. In addition, NodeMCU is used as Wi-Fi module, beside act as microcontroller that provides connection between user's smartphone and the project devices. In software design, a BLYNK apps is used to create software applications for the Android operating system.

Fig. 1 shows that as the project is running, the microcontroller will initialize all the sensors and connect them to the Wi-Fi module. The Arduino MEGA has based Atmega 328 and has 14 digital inputs and 6 analog inputs. After the initialization, the pH probe that connected to the pH circuit will sense and measure the pH value of the water inside the aquarium and display it on the LCD display. The analog pH sensor kit is used as it is designed for pairing with the Arduino MEGA. Hence, if the feeding time has come, the users get to decide whether to feed it or not. As they decide to feed the fish, the users need to connect to the Wi-Fi and do the feeding process by pushing the button in the android software. Then, the servo motor will rotate in order to release the fish pallet. The Wi-Fi module used is NodeMCU as it is more compatible compared to other types of Wi-Fi module. Besides, the servo motor is used as it is suitable for 180 degree movement which make the feeding process more smoother and systematic.

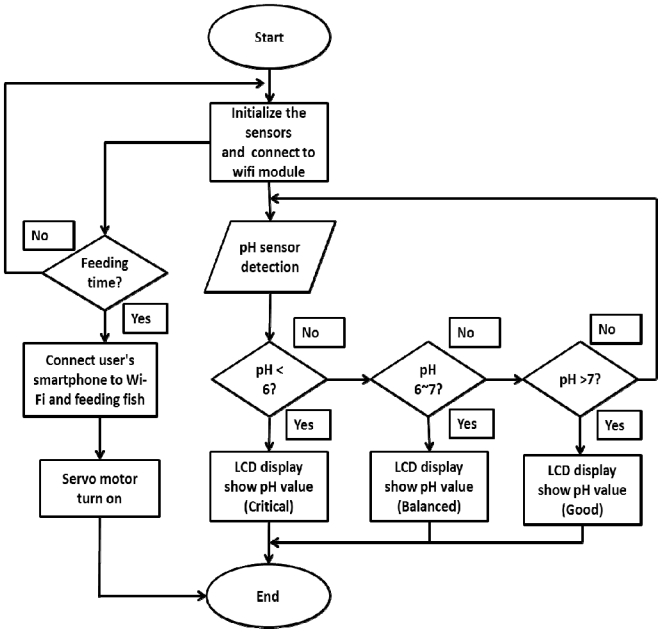

Fig. 1. Flow chart process of the project

IV. RESULTS AND ANALYSIS

The project result has been carried out into 3 sections which are Phase 1, Phase 2 and Phase 3. In phase 1, the result shows the functional testing of the sensor and actuator calibration. The result of combination the components to form a full system of an IoT-based Smart Aquarium Monitoring System, but it not yet can connect to the internet are being analyzed in phase 2. In phase 3, the additional of Wi-Fi module, NodeMCU show the connection between the devices and the apps. The data collection from the system can be access through the apps.

A. Phase 1: Components check with Data Analysis and preparation of an aquarium

In Phase 1, the process will take place here are component testing, preparation of the aquarium and the four set of tests for different case and situation of aquarium. The analysis carried based on the result from the components. The phase one contains four set of test. The entire test for each case is carried within 7 days. The first and second case test is carried without water pump filtration. The first test is feeding the fish 2 times per day while the second set is feeding the fish 3 times per day. Meanwhile, the third and fourth case test is carried with water pump filtration. Obviously, the third test is feeding the fish 2 times per day and fourth test is feeding the fish 3 times per day.

1) pH sensor module test (SKU: SEN0161)

SKU: SEN0161 is the sensor that can be used to measure pH value of the water. The detection is quiet high which are

from 1.0 to 14.0 reading of water value. There is a closed plastic cover filled with distill water should be remove at the top end of the sensor rod, before testing the sensor. Obviously, the sensor is very sensitive, as it should be covered all the time. The calibration is done by testing 2 types of water which are lime water and distill water. The coding used is simple pH detection and it is suitable pair to Arduino kit. The calibration shows that the pH sensor is working perfectly as the detection for lime water is acidic while the distill water is neutral.

2) Servo motor test

There are lots of servo motors available in the market and each one has its own ability and applications. The most suitable servo motor for this project is model sg90. This servo only can rotate until 180 degree of angle which means it just meets the requirement for this project. Other than that, this servo is used to hold a small container that filled with fish pallets. With the limitation of 1.80kg holding torque (at 4.8V), it seems not have a problem to hold that container. For the beginning, the calibration is done by using simple code of the rotation of 180 degrees, with infinite looping. Originally, the delay timing of the rotation is set to 1000ms, but it was too fast for fish feeder as it just a little pallet falls into the aquarium. To overcome this issue, the rotation is set to two rotational each feeding session, so that the pallet can fall as much as the fish's need. Each feeding session of the servo motor can feed the fish about 13-17 pieces of pallets.

3) Set up An Aquarium for Data Analysis

The aquarium has been set up with 13 litre of water. This size of aquarium is enough for the analysis which is it not too small or too big. There are 2 climbing perch fishes (Anabas testudineus), also known as 'ikan puyu' are used for this project. This fish was selected because they are very hardy can survive in any condition of water. The selection of the fish is very important because within the analysis process, there should be no harm or torture to the fish. As the climbing perch fish is one of hardy animal, it is easily to jump out from the aquarium. This is clear that the precaution should be taken to avoid that happened. The top of the aquarium should be closed during the data analysis. Even these climbing perch fish jump out of the aquarium, they can survive for several hours without water.

4) Initial Analysis

After setting up the aquarium, anti-chlorine should be added because the water used directly from the pipe. The normal water directly from the pipe is contained chlorine that used to kill germs, but it is very harmful for fish as it made up of combination of certain chemical substances. By applying the anti-chlorine, it changed the pH value of the water. The pH value of the water directly flow from the pipe is about 7.79 while after applying the anti-chlorine, the pH value drops to 7.61. The high concentration anti chlorine brand NIKA has been used with 1 drop per 4.5 liter. This proved that anti-chlorine usually only neutralizes the chlorine portion and leaves the ammonia part which is harmful to the fish.

5) Recalibrating the pH sensor (Sudden Change)

This process take place during the data collection of each set of analysis as it can be occurred anytime. During the analysis, it was found that pH sensor is very sensitive compared to the other sensors. There was a sudden change pH reading compared to the actual reading during collecting the data. The improvement scale of this calibration is very far which is 3.0 of pH value. To overcome this issue, the calibration has been made from time to time. This calibration takes place with testing the water from water ionizer which is normally used at home. The reading of water from this water ionizer is quite accurate which is reading of 9.5 pH value for water drinks. Then, the mineral water brand DESA has been tested which is 7.20++ pH reading to make it as referral water pH scale for further calibration if got some error.

6) Case 1: Feed the fish 2 times per day

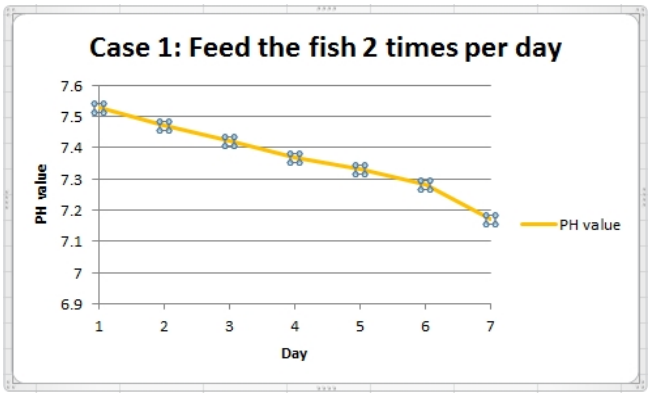

Fig. 2. pH value when feeding the fish 2 times per day

Fig. 2 shows the graph of pH value when feeding the fish 2 times per day. The feeding time is at early morning and late evening. The graph shows that the pH value keeps decrease with range of 0.04 to 0.09 decrement. This prove that the existence of the fish affects the pH value of water as the fish keep eating and release the waste. However, the pH value of the water keeps inside the range of neutral reading, which it is the optimum pH level for the fish. In addition, during this case, the fish are in the tranquillizing condition as they keep swimming around actively inside the aquarium.

7) Case 2: Feed the fish 3 times per day

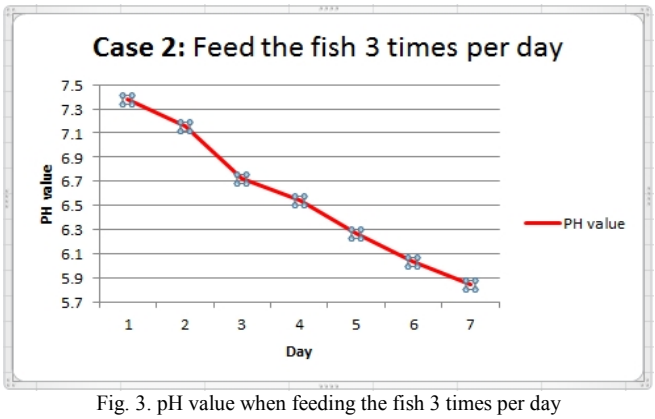

Fig. 3. pH value when feeding the fish 3 times per day

Fig. 3 shows the graph of pH value when feeding the fish 3 times per day. In this case, the feeding time is at early morning, afternoon and late evening. During this case analysis, the pH values of water keep decreasing from day to day. The range of decrement is about 0.15 ~ 0.22. The decrement is double from Case 1. This is due to the fish was

overfed as they cannot eat the entire pallet that user give them. The remaining uneaten floating pallet had rot as the chemical byproduct of that pallet breaking down inside the water. This may increase the toxicity of the water and unwanted algae start to grow. The water inside aquarium becomes cloudy, as the maintenance need sooner. The pH value of the water had reached the acidic range, which is harmful for the fish. As the result, the fish are in passive mode as they are in stressful condition.

8) Case 3: Feed the fish 2 times per day (with mini water pump filtration)

Fig. 4 shows the graph of pH value when feeding the fish 2 times per day with mini water pump filtration. This is same like in the Case 1, the feeding time is at early morning and late evening. During this case analysis, the pH values of water keep decreasing from 0.03 to 0.05 each day. Even that, the pH value of the water keep maintained in range of neutral reading, which it is the optimum pH level for the fish.

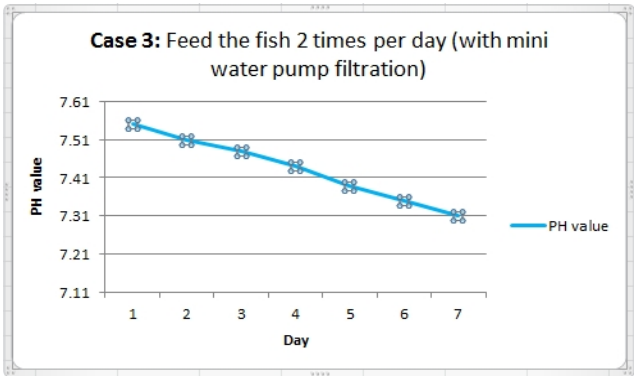

Fig. 4. pH value when feeding the fish 2 times per day (with mini pump filtration)

Based on the graph, the 7th day of the analysis in this case is slightly better compared to in Case 1, where there is 0.14 improvement of pH value of water. This proved that additional of water filtration system is very helpful and important in order to keep the water inside aquarium remains clean and the pH value is inside the neutral condition.

9) Case 4: Feed the fish 3 times per day (with mini water pump filtration)

Fig. 5 shows the graph of pH value when feeding the fish 3 times per day with mini water pump filtration. This is same as in the Case 2. During this case analysis, the range of decrement of pH water is about 0.07 ~ 0.09. Even that, the pH value of the water keeps maintained in range of neutral reading but become acidic on 7th day which is 6.98 on pH reading. During this analysis, it was found that there is another factor that can affect the pH value of water which is improper digestion of the fish. Improper digestion of the fish leads to pollute the condition of the aquarium because the fish are producing more waste than usual, and this make them look shaggy and colorless.

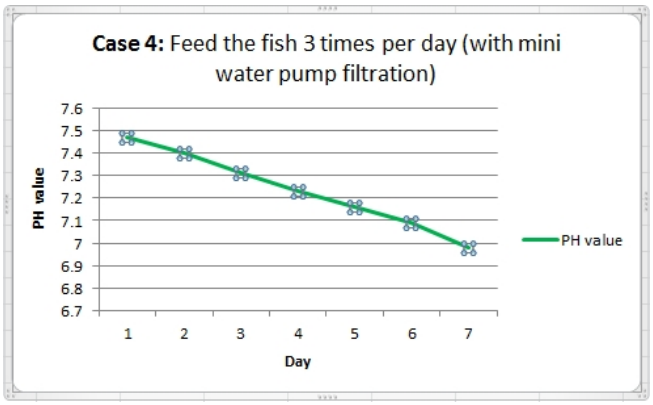

Fig. 5. pH value when feeding the fish 3 times per day (with mini pump filtration)

10) Comparison of all cases

Fig. 6 shows the comparison of the pH value for all cases. The data shows that aquarium water with filtration system is take time longer to become acidic compared to aquarium without filtration system. The filter cleans up the water of debris while removing the buildup of toxic such as ammonia and nitrates where they are chemical byproduct of the pallet. The most danger part for aquarium without filtration is overfed the fish as it can multiply the decrement of pH value rapidly. In the same time, overfed and improper digest of the fish can affect the decrement of pH value of water neither with filtration nor without filtration system. To overcome it, the user should know the size, quantity and type of fish that they keep. The user should feed the fish on a schedule where most of aquarium will do well if fed twice daily.

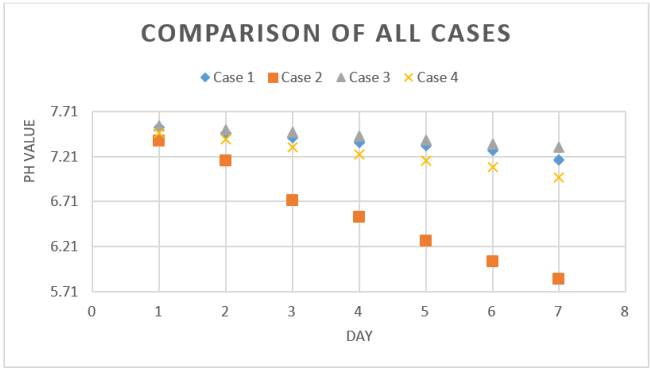

Fig. 6. Comparison of the pH value for all cases

B. Phase 2: Combination of all part of component

For phase 2, all the components has been combined together to form the full system of an IoT-based Smart Aquarium Monitoring System. Troubleshooting is needed as the connection of the circuit must be correctly connect each other. The solder lead used for the circuit should be good quality in order to avoid poor electrical connectivity between the board and components. During hardware connection, the dupont wires should not be forced into the connector because they are easily break and lose contact. The connection should be systemathic, smooth and rigid.

Fig. 7. The front view of prototype

Fig. 7 shows the front view of protoype of the system. The design inspired the concept of the modern house's roof. This protoype is attachable, where it just need to be place above the aquarium. There is a 16x2 LCD display at the front of the protoype. It shows the pH value at the first line of LCD display, while showing the notifier for condition of the water's health at the second line of the LCD display. There are three level condition of water that notifier shows, which is critical, balanced and good. For critical condition, the pH value reading is below 6.0, which is the water is not good for fish and the water maintenance should be done by user immediately. For balanced condition, the pH value reading is between 6.0 and 7.0, which is the water is still in balanced condition but the maintenance is needed as it reach to 6.0. For good condition, the pH value reading is above 7.0, which is the water is perfectly for the fish habitat.

Fig. 8 shows the top view of protoype of the system. There is three boards fit inside the protoype, which is blue for Arduino MEGA, red for NodeMCU complete with I/O sheild and yellow for extended supply board. The extended supply board design to add 5V and 3V supply from Arduino MEGA, as the NodeMCU just need 3V of supply. Meanwhile, the other components such as servo motor (sg90), 16x2 LCD display and pH sensor (SKU: SEN0161) only need 5V as power supply. There is a black section, where is a space for power supply such as battery or power bank. Even that, the supply can directly use from the socket with the USB adapter like usually used for phone charger. At the centre top, there is a square hole for the pH sensor go through inside the aquarium. At the right top of the prototype, there is space for mini water pump filtration.

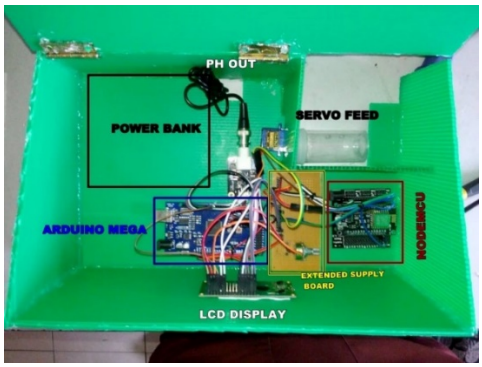

Fig. 8. The top view of prototype

C. *Phase 3: Complete system with IoT application*

For phase 3, the system is connected with Wi-Fi. The connection through Wi-Fi is performed by Wi-Fi module NodeMCU through the coding used on Arduino IDE. Fig. 11 shows the system through BLYNK apps. At the beginning, the user should make account to log in to the apps. After that, the 'auth token' will be send to the user's email adress which is used to link that token code inside the coding through the arduino IDE. Then, the ssid (wifi id) and its password should be set into the coding so that the wifi module NodeMCU can connect it automatically as the power is on. Initially the user given 1900 point to add the widget. Each widget has different cost of point. For the system, button and gauge meter widget had been used where button for feeding the fish, while gauge meter for pH value monitoring. In the same time, notification and eventor windget has been used as a notifier of the system . The notification notify user with beep sound and display text as the range of pH level changes. In addition, there is a small notification at the buttom of the screen, notify the user either the device is connected to the internet or not.

CONCLUSION

As the conclusion, this project can give many advantages to the people especially amongst the fish keeper nowadays. It is very helpful to monitor the pH value of water and ease the feeding process of the fish. The development of the Internet of Things (IoT) is very helpful for the smartphone user in this era. From the operation, this project is using pH value coding as the main part of the project. The pH sensor is used to read the pH value as it monitors the pH value for the user. As the result, user can know whether the condition of water is comfort or need to be replaced to the new water. In the same time, with the IoT features for feed the fish, it automatically can ease the user to feed their fish every time and everywhere. Now, people don't need to worry about their fish, if they keep busy outstation for either work or vacation. The experience to reveal the new thing is very useful especially on making new things in order to make it useful for people's future prospect. Lastly, this Smart IoT Aquarium is one of the new ventures and very useful for fish keeper all around the world.

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