

Smart Aquarium Water Quality Monitoring and Changing for Ornamental Fish Store using IoT through Data Mining



Sumitra Nuanmeesri, Lap Poomhiran

Abstract: Raising beautiful fish to live longer, the fish keeper needs to take care of the water quality of the fish that live in particular. The quality of the water may decrease all the time and cause fish to die in the end. This research presents a smart automatic water changing system for ornamental fish shops. It was developed with IoT devices in conjunction with sensors for measuring the indicators that affect water quality, including temperature, turbidity, total dissolved solids, the potential of hydrogen ion, dissolved oxygen, and nitrate ion. The collected indicator data was processed in the data mining technique by using the Apriori algorithm to generate 18 association rules and the preset of system configuration that suitable for raising angelfish, goldfish, guppy, platy, and Sumatran tiger barb which are tropical fish in Thailand. The result shows that the developed system has the highest efficiency with the accuracy at 99.67% in an average mean. It can be said that the smart aquarium water quality monitoring and water changing is helping the fish keeper at the ornamental fish store at the highest level.

Keywords: Apriori, aquarium water quality, data mining, esp32, internet of things, ornamental fish.

I. INTRODUCTION

Raising fish as a pet has been very popular since the first time when interacting with animals. By raising fish that can help reduce stress and blood pressure. Some studies have shown that pets help to reduce loneliness, as well as improve social feelings and emotions [1][2]. It is found that raising fish also helps in the treatment of adolescents with diabetes to better control the disease [2]. Besides, raising fish is suitable for people who want to raise animals that do not have time to care for pets [3] and is suitable for children who are beginning to raise animals.

For businesses that raise fish or fish stores that sell ornamental fish, they often encounter inadequate fish care. The reason may be due to the insufficient number of staff or caretakers for the number of fish or the number of ponds or

fish tanks. The more fish there are, the more care is needed. Especially small fish or fish that are sensitive to the environment, so special care is needed to reduce the chance of death of these fish [4]. For a fish to survive for a long time, there are many factors such as water temperature, turbidity, total dissolved solids (TDS), the potential of hydrogen ion (pH), oxidation-reduction potential (ORP), electrical conductivity (EC), the oxygen level in the water or dissolved oxygen (DO), nitrate and phosphate waste. Some studies have found that some values have a direct relationship: ORP values are related to DO [5] and EC values vary according to TDS [6], so some values may be used to represent each other. In which these values directly affect the quality of the aquarium water in which fish live. Changing water is another way to improve the quality of water. Most of the time, water changes in the tank only partially, such as 10% to 20% of the size of the fish tank for small fish or 20% to 30% for fish of medium size and up. In some cases, water may be exchanged up to 50% of the size of the aquarium. In some cases, water may be exchanged up to 50% of the size of the aquarium. It depends on the differences in species of each fish that are different in their ability to withstand environmental changes, especially new water. In addition, the frequency of changing water directly affects the quality of water and the quality of life of fish. Most of them prefer to change some water every week for small fish or a few fish in the tank. Larger fish that are more resistant to the environment may change the water every two weeks or at least once a month. The frequency of water change may depend on the amount of food used in fish farming. If there is a large amount of feeding or a high frequency of feeding, it will cause pollution more easily due to food scraps or fish droppings. In some aquarists, they want the fish to grow rapidly, therefore feeding the fish many times a day is necessary to change the water every day [7]. Having a good filter system will help extend the time for water changes. However, if the quality of the filter system decreases or after a certain time, it can be observed that the quality of the water in the aquarium begins to change or the quality decreases. For example, if the turbidity occurs or clouds in the water, the fish growers still need to change water as before. Also, maintaining the water quality suitable for each fish species is not an easy task as some values are not visible to the naked eye. Having the right measuring equipment that can measure and report results at any time will help fish keepers to know the quality of water used in fish farming to be suitable for fish habitat or to change the water immediately or not.

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Currently, many tools help to test and measure the quality of water for measuring various substances in the water. There are many kinds of tools and methods to test water quality.

Most of the instruments that need to be done manually by measuring only one indicator of the water values. If a fish keeper wanting to use the automatic meter will be quite expensive, especially the tools that can measure many different indicators as well.

Generally, the care for much ornamental fish in the fish store is not easy to achieve a good life quality and survive safely with suitable aquarium water quality. If the fish stores want their fish to have a good quality of life, it may be necessary to use higher costs as well. Today, many different technologies help improve the quality of life, especially the internet, computer technology, and the internet of things (IoT). This encourages tools and equipment that can be fabricated and utilized in a variety of ways at a low cost. There are many kinds of IoT boards such as Arduino, ESP8266, and ESP32. These boards are supporting the programmer to develop any system with internet connection ability. Therefore, this work purpose to develop the smart aquarium water quality monitoring and water changing for ornamental fish stores by using the IoT to control water changing automatically, and to help fish growers and reduce the burden of maintaining fish to live and grow normally.

II. RELATED WORKS

Before develop the smart aquarium for the water quality monitoring and automatic water changing for the aquarium in the ornamental fish stores, the researchers have compiled relevant information and related works as follows:

A. Physical properties of water

The physical properties of water can be divided into two main parts: temperature, and the turbidity of the water.

- *Water temperature:* The water temperature affects the fish's livelihood a lot. Because fish are cold-blooded animals. The body's temperature, fish, or metabolic processes change depending on the water temperature. During the low temperature or in the winter, the various processes in the fish will also decrease. This is equal to inhibiting the growth, feeding, and breeding of fish. Although Thailand is in the tropics, the fish growth potential is better than in other cold countries. However, there is a winter period that lasts for one to two months, which must be considered a period that is enough to damage the fish. Each fish species may have different temperature requirements. For example, fancy goldfish can live in water with temperatures at 50 to 80 degrees Fahrenheit (°F). It can grow well at temperatures between 68 °F and 74 °F [8], while the moonfish or southern platy need a temperature between 70 °F to 77 °F for growth [9], or the molly fish prefers temperature 78 °F to 82 °F [10]. Besides, during each breeding season, some fish require a suitable temperature for reproduction different from their normal life. For example, goldfish breeders need temperatures between 64.4 °F and 68 °F while swordtail, platy, guppy, and molly fish need temperature in the optimum range 82.4 °F to 86 °F [11].
- *Turbidity:* It is the number of suspended solids in the

water. The turbidity of the water will affect the light-blocking, reducing the integrity of the fish pond or tank, and also clogging the respiratory system. Often causing small fish and eggs to die. This may be observed from colors that can be seen easily. Mainly caused by plankton, suspensions, and various solutions that dissolve in water. The new aquarium may not be visible until the accumulation of more can be observed. Most of them are caused by fine sand, dirt, silt, fish food scraps, and fish wastes.

B. Chemical properties of water

The chemical properties of water can be measured from various indicators, most commonly measured from the potential of hydrogen ion, dissolved oxygen, the total dissolved solids, and nitrate ion values as follows:

- *Potential of hydrogen ion:* The pH of a substance is an indicator of how much hydrogen ions it contains [12]. It is an index of the hydrogen ion concentration ($[H^+]$) of the water ionization as in (1) [13].

$$H_2O = H^+ + OH^- \tag{1}$$

The negative logarithm of hydrogen ion concentration was called pH as in (2) [14].

$$pH = -\log_{10}[H^+] \tag{2}$$

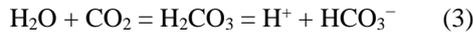
In aquaculture, the pH is an indicator of the acidity and alkalinity measurement in the water quality. It has values range from 0 to 14. Generally, pH value at 7 is neutral, below 7 is acidity, and over 7 is alkalinity. According to Yokogawa [15], they found that fish cannot be live in the water with a pH below 4, and 11 or more. The suitable pH for fish is 6.5 to 9. It can be illustrated as Table I [15].

Table -I: The pH impacts on fish

pH value	Impacts on fish
4	Fish death point in acidic
4 to 5	No reproduction
4 to 6.5	Slow growth
6.5 to 9	Desirable ranges for fish reproduction
9 to 10	Slow growth
≥11	Fish death point in alkaline

- *Dissolved oxygen:* Oxygen is necessity for any aquatic animals such as fish. The oxygen is generated from atmosphere and green plants. It can more dissolve in the water at a low temperature with low salinity and high pressure [11]. According to Harun et al. [15], the water quality standard for fish production, in general, the minimum DO values between 4.0 and 5.0 milligrams per liter (mg/L) for a huge of varieties of fishes. In usually, after the sunset, the photosynthesis is deactivated. All fishes and plants in fish tank or pond will consume the oxygen then releases the carbon dioxide (CO₂) which can cause the carbonic acid (H₂CO₃) that toxicity to fish and effect on water to low pH value. The carbonic acid is formed as in (3) [16].





So, during daylight, the DO and pH will be increasing while CO₂ is decreasing. At night, the DO and pH are decreases and CO₂ is increases [16].

▪ *Total dissolved solids:* TDS is the dissolved ions concentration. TDS contains both organic and inorganic which has benefits and toxicity to quadratic animals. Some sources of water may contain organic pollutants or some industrial treatment of water such as contaminants which are toxic metals [17]. In some areas found inorganic salts, with a variety of organic matter dissolved in water such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates in small amounts [18]. TDS can cause toxicity by increased salinity [17] which is factor of fish survival, metabolism, and fish's reproduction. It affects to teleost such as egg and larvae [19]. Besides, salinity also affects fish growth for large fish [20].

▪ *Nitrate ion:* Normally, nitrate is a polyatomic ion that molecule formula of the nitrate ion (NO₃⁻). Nitrate is a nitrogen oxoanionic formed of nitric acid. The nitrate is produced from the nitrogen cycle caused by humus or fish waste. Beginning with fish feces or wastes from any uneaten foods were turned into ammonia (NH₃), then benefits bacteria convert ammonia to nitrites (NO₂⁻), and finally in the form of nitrates. The nitrogen cycle in the aquarium is shown in Figure 1.

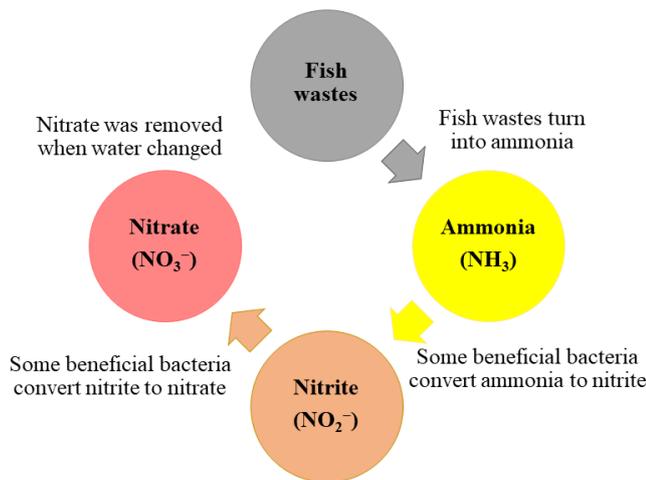


Fig. 1. The nitrogen cycle in the aquarium.

Nitrates have a direct impact on fish by causing their blood hemoglobin levels to drop, resulting in the oxygen intake system failing to eventually die [21]. Low nitrate concentrations are not toxicity to fish, but can cause other problems in the water [22]. Usually, nitrates were removed from water by changing water system such as raining or partial water change in aquarium. Also, the suitable way to reduce the nitrate in the water is often partial water changes [22]. Some aquarium applied the bio ball, bamboo, and gravel to remove the ammonia, nitrite, and nitrate from the water [23].

Therefore, this research proposes to develop the smart aquarium water quality monitoring and water changing for ornamental fish stores by using the IoT to control water

changing automatically with the association rules technique as the preset values of system configuration in the new aquarium.

III. RESEARCH METHODOLOGY

In this research, the process of developing the smart aquarium water quality monitoring and water changing automatically by using IoT and data mining, the system methodology was presented as the following steps:

A. Data acquisition

This is the first stage for developing the smart aquarium water quality monitoring and water changing based on data mining technique. In this work, we addressing the frequency of partial water changing and full water changing when the water is low quality or reach the critical of the threshold values. The researchers collecting the data from different ornamental fish stores and focusing on five favorite kinds of tropical fish in Thailand. There are angelfish, goldfish, guppy, platy, and Sumatran tiger barb. The data was gathered by observing, an interview with the fish keeper, and measuring the factors that related to aquarium water quality and water changes. There are 250 records in total of data that related to these parameters: water temperature, pH, turbidity, TDS, DO, nitrate ion, and percentage of water changes.

B. Data mining

At this stage, the data was processing with data mining technique by using the Apriori algorithm in Weka version 3.8.4 which is the famous free mining software that developed by Waikato university. The 250 records of data were prepared in form of csv file which has 11 features and one class to decision for water changing. All features were shown in Table II.

Table -II: All features related to aquarium water quality and water changing

No.	Feature	Feature description
1	Fish_kind	Kind of fish (Angelfish, Goldfish, Guppy, Platy, Sumatran tiger barb)
2	pH_min	The lowest pH before changing water.
3	pH_max	The highest pH before changing water.
4	DO_min	The lowest dissolved oxygen before changing water.
5	TDS_max	The highest total dissolved solids before changing water.
6	Nitrate_max	The highest nitrate before changing water.
7	Temp_min	The lowest water temperature before changing water.
8	Temp_max	The highest water temperature before changing water.
9	Turbidity_max	The highest turbidity before changing water.
10	Percentage	The percentage of water change.
11	TypeOfChange	Type of water changes (partial, full)

The csv file formatted in 12 columns (11 features and one class) were processed based on association rules with the lower Bound Min Support value was 0.1, and min Metric was 0.9.

- *Automatic water changing:* During all IoT devices and sensors are working, if the data from the sensors meet one of all criteria defined as 18 association rules, the system will start to mode water changing until the water quality is turned into normally or end of the process of water changing for each period. When water pump is active for drain the water in aquarium, the ultrasonic sensor will be monitoring until the minimum level of water has reach. The water pump will stop working and active the automatic water filling process.
- *Automatic water filling:* The automatic water filling will work only if the situation meets one of the two conditions as follows: the water was evaporation in the natural life cycle of water, or the water quality is low and meets the 18 association rules then the water pump is already done. The solenoid valve will change status as open then fill the new water in the aquarium. Until the level sensor activated by the current water level has reached, the solenoid valve will change the status to close for stop water filling.
- *Automatic notification:* For all critical events are occurred, the IoT system will send the notification as message into LINE Notify application on internet. The fish keeper can monitor the aquarium by viewing the message from IoT system shows as Figure 3.

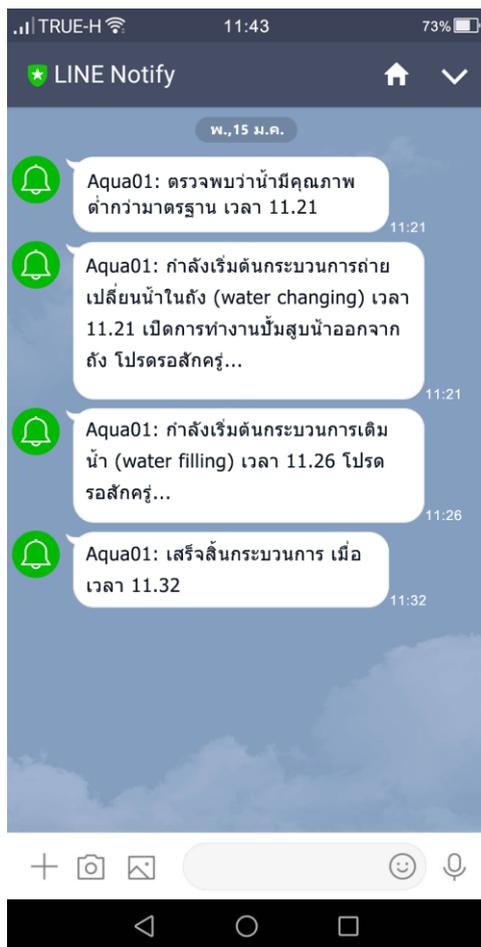


Fig. 3. LINE Notify message from IoT system.

- *System real-time monitoring:* This is a final part of smart aquarium water quality monitoring and changing system. The researchers develop a web application for fish keepers to monitor the aquarium status in real-time from

the webserver which is implemented on the central server. The username and password are required to access this web application for real-time monitoring.

E. System evaluation

The smart aquarium water quality monitoring and changing for the ornamental fish store using IoT, it was evaluating the efficiency of the system by users who is a fish keeper or worker at ornamental fish stores which are install the developed system too. The users were training how to use the system and tried to install the system by themselves. The researchers keep the data logging of each IoT system from microSD card in ESP32 board, then double cross checking with users and logging on the central server in one month for evaluate the overall system.

IV. RESULT AND DISCUSSION

The smart aquarium water quality monitoring and water changing was setup and install at ornamental fish store which has one of five kind of fishes: angelfish, goldfish, guppy, platy, and Sumatran tiger barb. The data from IoT system in microSD card, logging on a central server, and users were evaluated for each store in one month. The result of system accuracy shown in Table III.

Table -III: The accuracy of smart aquarium water quality monitoring and changing for ornamental fish store

Term of evaluation	Accuracy (%)
1. The preset values for new aquarium system configuration.	100.0
2. Auto water changing when water quality is low or critical.	99.0
3. Auto water filling when water evaporated in natural.	100.0
4. Auto water filling when water quality is low or critical.	100.0
5. Auto notify message.	100.0
6. User monitor in real-time.	99.0
Average mean	99.67

According to Table III, it found that the accuracy meets 100.0% in three term of evaluations, there are the preset values for new aquarium system configuration, auto water filling when water evaporated in natural, and auto water filling when water quality is low of critical. Considering to auto water changing when water quality is low or critical, the accuracy value at 99.0%. In some aquarium, the all data from sensors do not meets the criteria in 18 association rules. So, the automatic water changing does not active. For user monitor in real-time, the accuracy value at 99.0%. It is some delay in a minute because this system was designed for save power consumption. All sensors for temperature, pH, DO, TDS, turbidity, and nitrate ion were activated for every five minutes. In overall system, the average mean of accuracy is 99.67%. This IoT system can be working for monitoring and changing the water quality in aquarium at the highest level.



V. CONCLUSION

This research presents the smart aquarium water quality monitoring and water changing in ornamental fish store based on IoT and applied the Apriori algorithm in the data mining technique to determine the association rules which are related to five kinds of tropical fish in Thailand and the basic of water quality indicators. The temperature, pH, dissolved oxygen, total dissolved solids, turbidity, and nitrate can be measured by each sensor in IoT devices. The data from various sensors are processed according to the 18 association rules to decide to order the system to change water automatically. Users can monitor their aquarium in real-time via LINE notify application or web server which has security to access their information. Therefore, this smart aquarium water quality monitoring system could be helping the fish keeper and save their fish live in the aquarium at ornamental fish stores.

For further works, we will expand the scope to cover several kinds of fish and collect more indicators that effects to water quality and life of fish in the aquarium. Furthermore, we will develop the automatic maintain the aquarium system in a complex by using data mining in adaptive preset configuration based on real-time output data from sensors at any ornamental fish store where implement this system.

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