International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Improvement of Smart Farm by using IoT for Ornamental Fishes and Aquatic Animals Store

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Abstract*: *Ornamental fishes and aquatic animals have long been popular pets that can be easily bought and maintained. In contrast, it is not an easy task for a store that sells or a farming farm. These fish need to be well-kept to survive before customers come to buy. But it is unlikely that these fish will be looked after thoroughly, especially the issue of water quality used in fish farming or store. IoT can help operators manage and maintain water quality automatically instead of a human. This paper proposes to develop and improve the aquarium system maintenance automatically by using IoT and sensors devices. The ESP32 board is used to control the aquarium system and sent the alert message which is related to the critical situation and event handling action to farmer or entrepreneur on social media in real-time monitoring. All data from sensors are kept in microSD and central server. User can config, adjust the threshold value, and control the aquarium system directly. The developed aquarium system has high efficiency with accuracy value at 98.75%. It helps and automatically improves the water quality for the ornamental fishes and aquatic animals at the stores and smart farms.

Keywords*: *aquatic animals, esp32, internet of things, ornamental fish.

I. INTRODUCTION

Human has kept fishes and aquatic animals as pets since former times when interacting with it can be helping decrease levels of stress and blood pressure. Some studies show that pets cause the reduction of loneliness, improving social feelings and mood [1][2]. According to News in Health [2], when treating fishes, diabetes teens can control their disease better. In the case of people who have no time or space to devote their time to a supervisory companion animal, fishes are suitable animals [3]. Even children can easily raise and take care of fish.

On the other hand, the business of beautiful fish farming and breeding or fish and aquaculture store, it has a large number of fish and fish tanks.

Revised Manuscript Received on January 30, 2020.
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Many aquacultures and fish caring may not be given thorough attention. Most of the fish being bought are small fish that need special care due to the high chance of death. Moreover, for cost saving, each aquarium tank will be containing a lot of fishes. It can cause an effect on the quality of water and life of fish directly. Especially the quality of water used for farming or tending is the main cause of the survival or death of fish. So, it is not easy to look after much ornamental fish and aquatic animals to have a good quality of life and survive safely.

Generally, it is a very difficult task itself to manage fish aquariums. If the water quality is a hazard to fish, it needs to clean up immediately. There are many steps to changing the water in tank. For example, first, turn off the power of aquarium devices such as air pump. Next, drain the water out of the tank then fill the clean water until enough to maximum level. Last, turn on aquarium power again. This is the basic steps for cleaning up the water by water changing manually. Regarding the aquarium system, good water quality saves fish life. It is very important to aquatic organisms. Good quality water consists of many features with indicators that can evaluate water quality in various numerical values, such as turbidity, Potential of Hydrogen ion (pH), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Oxidation-Reduction Potential (ORP), Electrical Conductivity (EC), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), etc. Some indicators might be related together such as DO and ORP [4], TDS and EC [5].

The precision technology can help in the aquarium caring and providing notifications via social media such as LINE will increase the chances of fish survival. IoT is one of the technologies that have capabilities to manage and control electronic devices automatically. With many sensors can be detect and measure the aquarium environment such as lighting, temperature, and the water quality.

In a field of IoT, there are several kinds of favorite of microcontroller unit (MCU) such as Arduino UNO R3, Arduino Mega 2560, NodeMCU or ESP8266, ESP32, Rasberry Pi, etc. Each kind of MCU has different features, it depends on developer or user requirements. For example, Arduino UNO R3 has six analog pins for analog signal input, and has 12 digital pins for programmable input and output (pin no. 0 and 1 are reserved for serial communication). NodeMCU or ESP8266 has 17 pins for input and output, but programmer can only use 11 pins in total. The Wi-Fi feature is included for ESP8266. In contrast, Wi-Fi feature is excluded for Arduino UNO R3 which has pin for input/output more than ESP8266. Considering to ESP32, it comes with 23 pins for digital and analog input/output. ESP32 has built-in Wi-Fi and antenna.

II. RELATED WORKS

In the development of a system to increase the efficiency of maintenance of fish and aquaculture systems. We have conducted studies and collected related research as follows.

According to Catalano et al. [6], goldfish requires the water tank clean. The total dissolved solids are priority parameter for the water quality. Both total dissolved solids and turbidity of the water varies with the temperature directly. If the temperature increases, the total dissolved solids, and turbidity will increase too. In general, total dissolve solids value is not over 2,999 milligrams per liters is safe.

The water temperatures are differently suitable for each kind of fishes. For example, the temperature between 68 and 74 degrees of Fahrenheit are suitable for raising fancy goldfish but shubunkins can live in water with temperatures as low as 60 degrees of Fahrenheit [7].

There are several researches develop an aquarium management system by using IoT. For example, ZigBee and IoT sensors were applied in aquarium system [8]. Tigadi et al. [9] use NodeMCU and IoT devices for controlling fish feeder, lighting, and temperature in aquarium system.

Some sensors can be applying to measure the water level such as ultrasonic sensor, float switch sensor, etc. The ultrasonic sensor and relay are used to detect the water level in [10]. To calculate the distance of water level, the velocity of sound was set as 340 meters per second.

Allafi and Iqbal [11] design the low power IoT system on web server based on ESP32 which is combined Wi-Fi to SD card module, and low-cost sensors. Biswas and Iqbal [12] apply the ESP32 microcontroller to control the solar water pump. The results were sent to web server and user can monitoring on mobile phone.

Therefore, this research proposes to develop and improve the aquarium system for ornamental fishes and aquatic animals at store by using IoT based on ESP32 which automatic control the water quality.

III. RESEARCH METHODOLOGY

In the process of developing a system to help improve the efficiency of maintenance for beautiful fish and aquaculture with the following steps:

A. System requirements analysis

At this stage, we conducted a study by collecting information related to the development of a system to increase the efficiency of caring for ornamental fish and aquaculture for stores. In this work, we address the quality of water and environments for the aquarium. There are four values of water quality; turbidity, pH, TDS, and DO. These four water quality data will be an indicator of the quality in beautiful fish tanks that have values that are suitable for raising ornamental fish and aquaculture in this developed system. Besides, the values corresponding to the environment for fish and aquaculture are brightness, water temperature, and water level required. Therefore, this system will apply seven parameters of water quality and environments to develop the automatic maintenance aquarium system in stores.

Moreover, we have studied and gathered information on a list of sensors that measure water quality required. Most sensors can be detecting the quality of water and system environments as analog values such as pH, DO, TDS, turbidity, and brightness. On the other hand, the water temperature and water level were detected as a digital value by sensors. For the detail of each sensor, we will describe in the next stage.

B. Aquarium system design

In this work, the aquarium system of ornamental fish and aquatic animals for the store was designed by using IoT devices and sensors as the follows.

- ***ESP32 DevKitC:*** It is a board in developed kit with Electronic Control Unit (ECU) which is microcontroller unit in series of Espressif ESP32-WROOM-32, total 38 pins included. In this research, the aquarium system requires 20 pins (voltage and ground are excluded) for digital and analog input-output the value or signal from IoT and sensor devices. Especially, the Wi-Fi communication is one feature that is included and it is a necessity in this work for sending and receiving data between server and notification system.
- ***DS3231 Real-Time Clock (RTC) module:*** The DS3231 RTC module was applied and kept track of the current time for other sensor activation and data recording to server. This module has its power source which is a 3V-3.6V battery for backup and continuous time keeping. It requires two special pins (SCL and SDA) for communicating with the ESP32 board. At stage of aquarium system initialization, the DS3231 module was synchronized the time from Network Time Protocol (NTP) server and stored the current time in itself.
- ***MicroSD card module:*** ESP32 can complete the file system to read and write the microSD card by using this module. It is a necessity to keeping and tracking information from sensors and all system configuration through the file system. During the water quality detection, the previous data or history data of the sensor were calculated and applied to automatic system decision and activation. There are four special pins (CS, SCK, MISO, and MOSI) are required to SPI communication in this work.
- ***DS18B20 temperature sensor probe:*** The DS18B20 probe is a small digital temperature sensor with 3-wires interface. This sensor can operate in liquid or water in two mode; normal mode, and parasite mode. Normal mode was applied to the automatic aquarium system. It requires 4.7k Ohm of pull-of resistor and three digital pins for output data, 5V of power source, and ground connection respectively.
- ***pH sensor module:*** It is an analog meter for pH measurement in water or liquid. Th pH sensor module consists of three components; pH electrode with BNC connector interface, analog cable, and pH sensor circuit board. The pH measurement levels are 0-14pH with accuracy value at ±0.1pH.

This module requires a pin for analog pH data.

- ***Dissolved oxygen (DO) sensor module:*** This module is used to measures the dissolved oxygen in the aquarium system. The dissolved oxygen is detected in analog value by BNC probe and analog signal converter board module. An analog pin is a necessity in this module.
- ***Turbidity sensor module:*** The level of turbidity can be detected by this analog sensor which is an optoelectronic instrument. It is able to detect the total suspended solids (TSS) or colloidal particles that harbor pathogens in the water by measuring the intensity of light scattered at 90 degree to the beam of light. An analog pin is required for signal output from sensor. The signal output will decrease when the turbidity level is high.
- ***Total Dissolved Solids (TDS) sensor module:*** It is a small analog sensor for measuring the total concentration of dissolved substances in the water. It needs an analog pin for output data to ESP32.
- ***Photoresistor sensor module:*** Photoresistor or Light Dependent Resistor (LDR) sensor was conducted to measuring of light intensity or brightness in automatic aquarium system. In this work, LDR sensor module was combined with potentiometer for control brightness of LED tube light in tank. A digital pin was reserved for this sensor.
- ***Ultrasonic sensor module:*** The ultrasonic sensor is used to detects and measures the minimum level of water that remaining in the aquarium tank. This module will be active when water pump starting for draining the water out of tank. Two digital pins are required for controlling this sensor.
- ***Horizontal water level sensor:*** It is a horizontal float switch. It was applied to control the maximum water level in aquarium tank.
- ***X9C103S digital potentiometer module:*** This module is adopted to increase or decrease the current for control the brightness of LED tube light.
- ***AD5290 digital potentiometer:*** This potentiometer is analog device which operate voltage between -15V and +15V. It is support for electronic devices in wide range of voltage such as 3V, 5V, 9V, 12V, and 15V devices. In this system, the voltage of air pump operated range between 6V and 12V and controlled by AD5290 potentiometer.
- ***Two-ways solenoid valve:*** This solenoid valve is a fluid or water control electronic valve. It is designed for 1.5 inches of water pipe and operated with 5V. This valve was set to Normally Closed (NC) mode. It will be opening when the minimum water level in tank was detected by ultrasonic sensor. In general, it must be used with a transistor and a diode in operation.
- ***Dual channel Relay (5V):*** This relay is used to switch and control air pump and water pump. Two digital pins are required for this relay.
- ***Water pump (12V):*** This pump is conducted to water draining from tank. There are wide range of water pumps. In this experimental, we use a simple of pump such as Sonic AP1200 pump. It has water flow rate at 600 liters per hour.
- ***Mini electric vacuum pump or air pump(6V-12V):*** In order to control the dissolved oxygen in the water, two mini air pumps with vary of voltage between 6V and 12V are conducted in this system. These two pumps were controlled by AD5290 potentiometer.
- ***LED tube light:*** The LED light is regulated used for aesthetic and intended for relaxation of fish and aquatic animals in aquarium system. This LED tube light can be dimmed and controlled by X9C103S potentiometer.

Therefore, all of IoT devices and sensors in this research are presented in Figure 1.

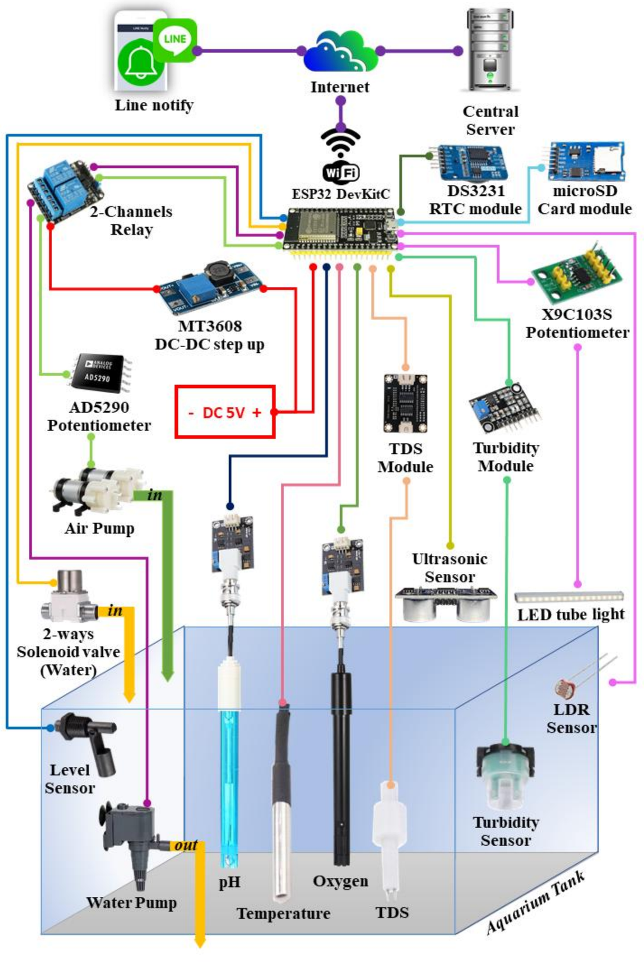

Fig. 1. IoT devices and sensors in automatic maintenance aquarium system.

C. Application development for ESP32

This application was developed in Arduino platform. We use Arduino IDE in version 1.8.10 as is software editor on Windows 10 x64. There are eight main parts for automatic maintenance aquarium system as the follows:

- ***System configuration:*** By default, the system was set the Wi-Fi connection into both mode; soft access point (soft-AP) mode, and station (STA) mode. For soft-AP mode, we develop and deploy the web application for ESP32 as a web server with local Internet Protocol (IP) address 192.168.0.1. User can setup and config system require information such as client id, client name, Wi-Fi username and password, LINE notify information, etc. For STA mode, after user setup and config Wi-Fi username and password for access Wi-Fi router, the ESP32 will be connect to internet. The microSD card module is used at this stage.

▪ ***System initialization:*** After ESP32 board or client is connected to the internet. The DS3231 RTC module will synchronize a current time from NTP server. For the first time of use, it will register client id of ESP32 with IP address into central server database then loading some configuration such as threshold values from server. The client id is requiring for recording data of sensors for each ESP32 board. For next time of use or system wake up from shutdown, ESP32 will load system configuration from microSD card module.

▪ ***Automatic light control****:* LDR sensor module measures the light intensity in aquarium tank during the daytime and turn off at nighttime. For period of nighttime, user can re-config or manual setup different from default value.

At daytime, if the light intensity is lower than threshold value of brightness, the X9C103S potentiometer will be decrease the step of resistor for increase the brightness of LED tube light. On the other hand, the potentiometer will be increase when the light intensity is over than threshold value.

At nighttime, LDR sensor is ignored. The X9C103S potentiometer will increase until the light intensity is 25 percentage of threshold value. This is relaxation for fishes and aquatic animals. User can adjust or define the percentage of dim by themselves. LDR sensor is considered when daytime is coming.

▪ ***Automatic oxygen filling:*** The dissolved oxygen was measured by DO sensor module. This is related to AD5290 potentiometer that controls the air pumps. By default, both air pumps are working with voltage at 6V. In case of the DO is lower than thresholding of DO, the voltages of air pumps are increasing to 12V in 30 minutes by AD5290. When a time 30 minutes passed, the voltages of both air pump are decreasing for every 10 minutes per a voltage until the voltage is 6V. For every voltage changing, the DO is measured and recorded in microSD card. After the voltage of air pump is back to 6V, the DO will be starting to measuring and recording for every 10 minutes in an hour. These six DO values were calculated and predict for the next DO value. If DO value trend to decreasing or lower than threshold value again, ESP32 will decide to changing the water automatically, then reset all DO value after the water were changed.

▪ ***Automatic water filling:*** In general, the horizontal water level sensor or float switch is continuous detecting the maximum water level in physical position of sensor in tank. If the water level is lower than position of sensor that installed, the solenoid valve will be open or active for filling the water. Until the float switch detected the level of water has reached the maximum level, the solenoid valve will set to Off (NC) again.

In case of changing the water, after ESP32 is start to controls a water pump for draining, the water level sensor will be ignored until the water pump is turn off.

▪ ***Automatic water changing:*** To changing the water in aquarium tank, it is depending on the parameters of water quality. There are five parameters for ESP32 make decision to change the water; turbidity, pH, TDS, DO and temperature.

Turbidity, pH, and TDS are highly sensitive condition for water changing. If the turbidity is higher than threshold value of turbidity or the pH is lower than minimum pH threshold or the pH is higher than maximum pH threshold value or TDS is over than their thresholding, ESP32 will action to changing the water in tank.

For DO value, the automatic water changing is active as condition of automatic oxygen filling. If the previous data or history data of DO is decreasing, ESP32 will act to water changing.

In most cases, the temperature will not change very quickly. Unless a sudden change from the climate. In case of the temperature is high than maximum threshold value that suitable for fishes and aquatic animals in tank. The ESP32 will decision to drain some water and automatic filling for decreasing the temperature. For lower temperature, the LED tube light is high priority to helps increase the temperature than water changing.

The action of automatic water changing is starting by these following steps. First, some sensors are ignored such as water level, turbidity, pH, DO, TDS, and temperature sensor. Second, water pump is activating to draining water. During water draining process, the ultrasonic sensor is activating to detect and measure the minimum level of water which is remain for saving the aquatic animal life. Third, when the remaining water level reached to the threshold of minimum level, the ultrasonic sensor and water pump are turn off then solenoid valve is opened. During solenoid valve is active or open, the water level sensor is activating again for measuring the maximum water level requires. Last, if the current water level reached the water level sensor, the solenoid valve is turning off, then all sensors (which are ignored at first step) are continuous considerate by ESP32.

▪ ***Automatic notification:*** The ESP32 will notify all activities which are related to critical or criteria of water quality by send the message or information to LINE Notify application via internet. User can turn on or off for each type of notification in system configuration, default all types status are turn on. Figure 2 shows the sample of LINE Notify when the turbidity value is too high.

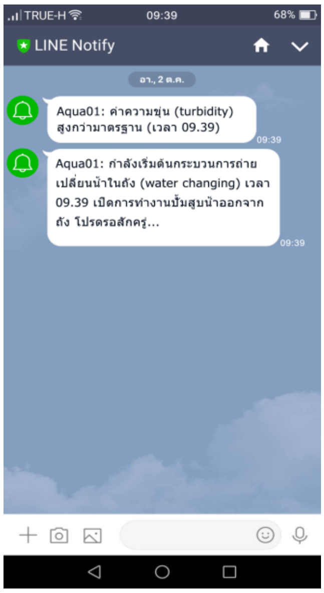

Fig. 2. LINE Notify message from ESP32.

- ***System real-time monitoring:*** We develop the web application for real-time monitoring the water quality in the aquarium system. In soft-AP mode of ESP32, user can monitor all water qualities by access the Wi-Fi access point of each ESP32 directly. In STA mode, user can access to web server at central server by login as username and password which is registered at system configuration stage. The data from aquarium clients were sent to a central server continuously.

D. System implementation and evaluation

To improving the aquarium system for ornamental fishes and aquatic animals by using IoT, we install and gather the efficiency of this aquarium system for ten aquarium tanks in different stores and locations within a month. The accuracy of this system is related to six terms of; auto light control, auto temperature control, auto water level control, auto water changing control, auto notify message, real-time monitoring. All information log of evaluation is recorded to central server and observed by farmers or entrepreneurs or operators at each store. Figure 3 shown a box set of IoT and sensors implementation.

Fig. 3. A box set of IoT devices and sensors implementation for aquarium system at fish store.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

After this system was installed and implementation at store or farm. We collecting the data from sensor and system action from logging on a central server then compare with data which are observed by farmers or entrepreneurs or operators at each store. The accuracy results of this system shown in Table I.

Table -I: The accuracy of aquarium system for ornamental fishes and aquatic animals store

Term of evaluation	Accuracy (%)
1. Auto light control	98.0
2. Auto temperature control	95.5
3. Auto water level control	100.0
4. Auto water changing control	100.0
5. Auto notify message	100.0
6. Real-time monitoring	99.0
Average mean	**98.75**

According to Table I, the accuracy results shown that in term of auto water level control, auto water changing control, and auto notify message are 100.0%. For auto light control, the accuracy value is 98.0%. Because of at some store, the aquarium tank is placed and too closed the front of store. Therefore, being exposed to sunlight and shining brighter than other areas. Entrepreneurs must be considering the place of aquarium tank location in the store. In term of auto temperature control, in this system, there is not much action in managing the temperature adjustment of the tank. By simply raising the temperature slightly by relying on the heat coming out of the LED Tube light. As for cooling the temperature, it relies on natural principles by transferring some of the water and then adding water that is only slightly cooler or room temperature. In case of real-time monitoring, the accuracy is 99.0% because of this system was designed to save the energy, thus the sensors do not active every second or all times. It has schedule for control the sensors for detect and measures the water quality in a background. Therefore, when user monitor system in real-time, there are some lagging of data in a minute. Considering of accuracy in average mean at 98.75%, this work can be managing the water quality system at a high level.

V. CONCLUSION

This work presents the development of improvement for ornamental fishes and aquatic animals in smart farm or store by using IoT and sensor devices. The water quality was detected and measured by sensors. The output data of any sensors were computed and decided to activate or deactivate electronics devices for control the quality of water which is suitable for fishes and aquatic animals. All data from sensors and handling action were logged in central server and microSD card at client of ESP32. All messages the meet the criteria or critical of water quality were sent to LINE Notify and alert to fish farmer or entrepreneur. Thus, this developed system is helping the farmer or entrepreneur to manage and control water quality automatically.

In future works, the heater and cooling system might be implemented for controlling the water temperature. And the big data from sensors will be mining to finding suitable water quality value for each kind of ornamental fishes and aquatic animals in smart farms or stores.

ACKNOWLEDGMENT

We are grateful for the Institute for Research and Development, Suan Sunandha Rajabhat University, who supported and gave an opportunity in this research.

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