Real-time Water Quality Monitoring and Notification System for Aquaculture

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***Abstract*—Fish Farming has been transforming through various technological revolutions in recent years, the Internet of Things (IoT) provides very significant technological innovations on farming by creating a new paradigm. This paper presents a water quality monitoring system with automatic correction four types of water quality parameters. The parameters are including temperature, potential hydrogen (pH) level, turbidity, and dissolved oxygen. The system uses sensors, micro controllers, and a mobile application for acquiring and monitoring data. The notification will be sent to user when those parameters are above or below the standard values. The Arduino Nano is used as controller unit to read the analog values from the sensors. Serverless IoTs is created using Firebase Realtime Database (RTDB) and ESP8266. The experiment has been conducted at Faculty of Fisheries Technology and Aquatic Resources, Maejo University.**

***Keywords*—Water Quality Monitoring, Serverless IoTs, Aquaculture, Mobile Application**

I. Introduction

Water quality is the most crucial factor involving fish health and performance in aquaculture production methods. Nowadays, fish farmers often face the problem of water quality. There is a number of reasons such as excess phytoplank- ton production, low dissolved oxygen and toxic metabolite accumulation. Different fish types have various and certain range of water quality aspects such as pH, temperature, oxygen concentration, hardness, salinity, and etc. The lack of effective monitoring of water quality and timely intervention in instances where there are changes in the quality aspects such as temperature and dissolved oxygen, has led to resource wastages and losses to the farmer due to low production. Most farmers rely on their experience when it comes to making decisions. The arrival of the Internet of Things (IoT) is opening various ways in which farmers can rare fish by simply installing inexpensive sensors which are able to communicate with smartphones and provide a means of monitoring and managing the fish ponds [1].

The main purpose of the research is to develop a smart farm prototype using IoT for high density sea bass farming in closed systems for environmentally-friendly and sustainable. This paper presents a water quality monitoring system by using IoT technology for aquaculture. This research is divided into two parts: to design sensor hardware and to develop mobile application. For water quality sensors, there are four types of water quality parameters. The parameters are including pH level, temperature, dissolved oxygen and turbidity. The system uses sensors, micro controllers, and a mobile application for acquiring and monitoring data. The notification will be sent to user when those parameters are above or below the standard values. The Arduino Nano is used as controller unit to read the analog values from the sensors. Serverless IoTs is created using Firebase Realtime Database (RTDB) and ESP8266. The experiment has been conducted at Faculty of Fisheries Technology and Aquatic Resources, Maejo University.

The rest of the paper is organized as follows. First, we described the related work in Section II. Second, proposed approach is presented in Section III. Third, we presented the experimental setup and results in Section IV. Finally, the conclusion is represented in Section V.

2021 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunication Engineering | 978-1-6654-1569-9/20/$31.00 ©2021 IEEE | DOI: 10.1109/ECTIDAMTNCON51128.2021.9425744

II. Related Works

Current studies in a diversity of research areas show rising interests in water quality monitoring system for aquaculture [2], [3], [4], [5], [6], [7], [8].

Y. Kim et al. [9] proposed a remote control and monitoring system of a smart aquarium by using IoT technology. Massage Queue Telemetry Transport (MQTT) is used to control a close loop water flow in the aquarium. Web application is used to display the sensor values in real-time. Android mobile application is developed for monitoring and controlling purposes.

In [10], S. Saha et al. proposed a system for monitoring water quality by using Raspberry Pi, Arduino, various Sensors, Smartphone Camera and Android application. Temperature, pH, electrical conductivity and color are measured. Android application is developed for monitoring the water condition through Wi-Fi within Wi-Fi range and through the Internet.

S. Nocheski et al. in [11] presented an improvement on a functional Internet of Things (IoT) approach for monitoring fish farming ponds. The temperature, light intensity and water level are measured. Wivity modem is used to connect to the IoT system using WiFi connection, cellular, LoRaWAN or satellite communication. This paper aim to deal with the remote area where no mobile and internet communication is available.

M. Niswar et al. [12] proposed an IoT-based water quality monitoring system for mud crab and blue swimmer farming. They use a lightweight Message Queuing Telemetry Transport (i.e. Raspberry pi MQTT broker) protocol and a LoRa-based wireless sensor network for sending messages between embedded devices, sensors and mobile devices. The sensor nodes are pH sensor, temperature sensor, and salinity sensor. User can monitor sensor data by using a web-based monitoring application.

In [13], Subramaniam, S. et al. presented a water quality measurement using IoT. A pH, temperature and turbidity sensor is attached. A prediction model is incorporated to the system in order to predict water quality levels. Seasonal Autoregressive Integrated Moving Average (SARIMA) is used as a prediction algorithm. MongoDB database is used to store sensor data. Web application is developed for monitoring data by using Node.JS.

Md. Monirul Islam et al. [8] proposed a system of cultivating fish farming using IoT devices. Water temperature, turbidity, PH, Water Level, CO3 gas are measured. ThingSpeak is used to collect and store sensor data in the cloud.

III. Proposed Approach

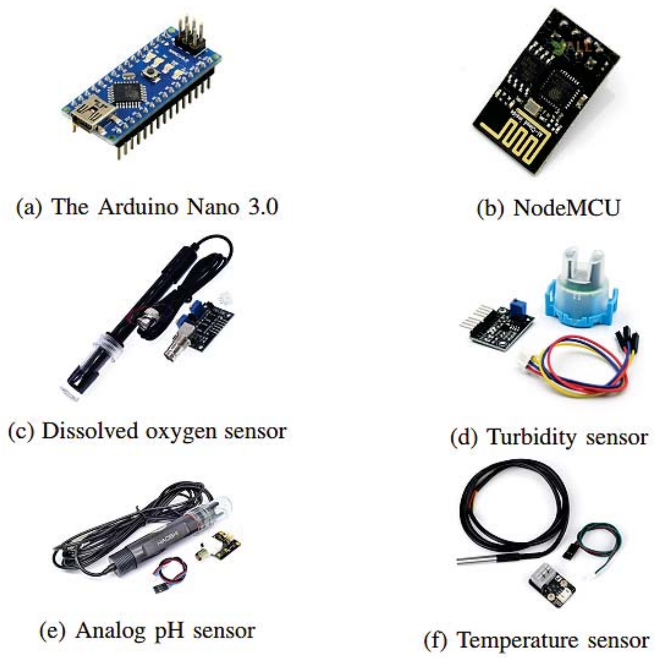
In this section, we introduce our Water Quality Monitoring and Notification System. Fig 1 shows a conceptual framework of our approach. This research is divided into two parts: (1) to design sensor hardware and (2) to develop mobile application.

The details of each part of this system are given in the following.

Fig. 1. Conceptual Diagram of Water Quality Monitoring and Notification System.

A. Hardware Design

The objective of this part is to develop a prototype using IoT technology for high density sea bass farming. Fig 2 shows the major components of our hardware system. The sensor devices consist of dissolved oxygen sensor, pH sensor, temperature sensor and turbidity sensor. The Arduino Nano is used as controller unit to read the analog values from the sensors. Serverless IoTs is created using Firebase Real-time Database (RTDB) and NodeMCU (ESP8266). The major components of the system are as follows:



(a) The Arduino Nano 3.0
(b) NodeMCU
(c) Dissolved oxygen sensor
(d) Turbidity sensor
(e) Analog pH sensor
(f) Temperature sensor

Fig. 2. The major components of the system.

The Arduino Nano 3.0 will function as a controller for our system. It is a small, complete, and breadboard-friendly board based on the ATmega328.

NodeMCU is an open-source Lua based firmware and development board for IoT based purposes. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif systems, and hardware which is based on the ESP-12 module.

Dissolved oxygen sensor is one of the essential parameters to indicate the water quality. It is galvanic probe with no need polarization time. Filling solution and membrane cap is replaceable and low maintenance cost. Detection Range is between 0 and 20mg/L.

Turbidity sensor identifies water quality by determining level of turbidity. It can detect suspended particles in water by measuring the light transmittance and scattering rate which changes with the amount of total suspended solids (TSS) in water. When the TTS rises, the liquid turbidity level increases.

Analog pH sensor is designed to measure the pH of the solution and reflect the acidity or alkalinity. The pH is a number between 0 to 14. To ensure accuracy, the probe needs to be calibrated for its first use and after not being used for an extended period (once a month if possible).

Temperature sensor is a waterproof sensor. Temperature display range is -10 °C to +85 °C

All equipments are assembled on the printed circuit board as shown in Fig 3.

Fig. 3. Electronic circuit board of Sensor nodes.

B. Mobile Application Design and Development

In order to monitor water quality values and notify to the users, we developed a prototype mobile application using hybrid technology (i.e. React Native) to support both iOS and Android platforms. The system is designed using object-oriented design. The scope of the system can be presented using a use case diagram as follows in Fig 4.

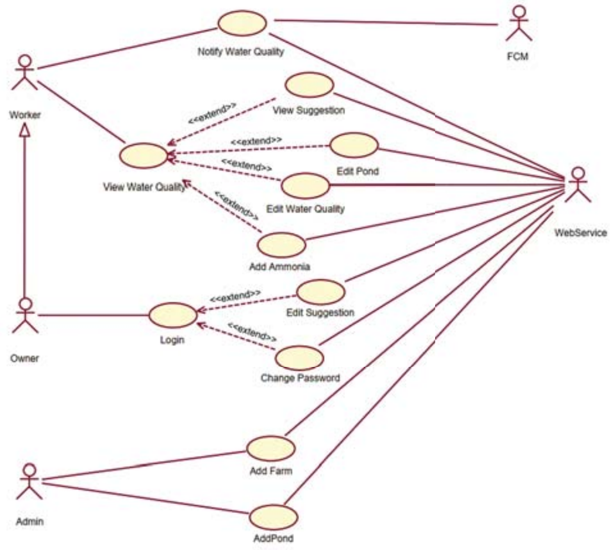


Fig. 4. Usecase diagram of water quality monitoring and notification system.

The features of our mobile application are listed below:

- **Notify Water Quality** : the notification will be sent to user when sensor value is above or below the standard value. Moreover, user will be notified when a sensor cannot read the value and sent it to the Firebase database for a given time frame.
- **View Water Quality** : user can monitor the latest water quality values in real-time.
- **View Suggestion** : users can view historical water quality graphs for a given time period. The suggestion will be given when water quality parameters reach out of acceptable level.
- **Edit Pond** : farm owner can change pond details.
- **Edit Water Quality** : user can define their own standard values (min and max values) of each sensor.
- **Add Ammonia** : user can add total ammonia value in to the app.
- **Login** : owner can login to the app in order to edit farm details and edit suggestion for his employee.
- **Edit Suggestion** : owner can add or edit suggestions for his employee what to do when sensor values above or below the standard values.
- **Chang Password** : owner can change his password.
- **Add Farm** : admin can add new farm into the system.
- **Add Pond** : admin can add new pond for specific farm.

The example of the mobile application can be shown in Fig 5. The algorithm for notification is shown in Algorithm 1. For monitoring, the color is used to indicate the water quality value. Red means the value is above the standard value while blue means the value is below the standard value. White means the value is normal but yellow means a sensor cannot read the value more than 30 minutes in our experiment. Morover, user can define their own standard of water quality in each sensor.

IV. Experiments and Evaluation

In our proposed monitoring system, water quality sensors play an essential role to measure the water temperature, dissolved oxygen, turbidity value, pH level of water in the fish pond. We conducted the experiments at Faculty of Fisheries Technology and Aquatic Resources, Maejo University as shown in Fig 6. In order to determine the accuracy of a particular measurement, two set of sensors are installed in the fish pond. All fish ponds are connected with pipes. The parameters obtained from the two sensors are compared. It

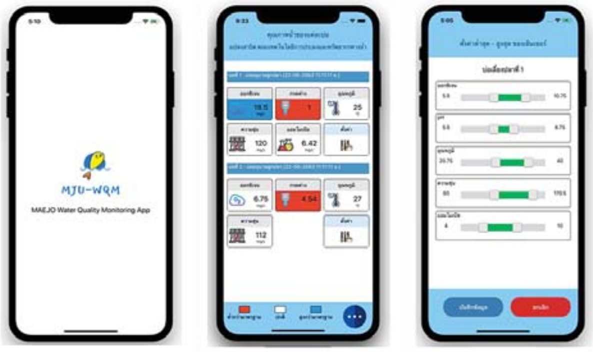


Fig. 5. Example of mobile application screens.

Algorithm 1: Notification Algorithm

```
message = "";
unread_sensor = 0;
read currentTime;
if curreentTime.minute mod x == 0 then /* every x minutes */
    foreach p in all ponds do
        foreach s in all p.sensors do
            ls = get lastestRecord of sensor s;
            if currentTime - ls.Time ≥ y then /* more than y minutes */
                unread_sensor + +;
                message = "sensor s is not active";
            else
                if ls.value ≥ max_value then
                    message = "above max value";
                else if ls.value ≤ min_value then
                    message = "below min value";
            end
        end
    end
end
if message ≠ "" or unread_sensor > 0 then
    send FCM warning message;
end
```

also compares the values obtained from measurements using manual tests.

To measure the performance of the sensor, we compared the measured data from two sensors measured at the same time for 30 days between 23/10/2020 to 24/11/2020 for each sensor. Table I shows the average difference between the two sensors of all four parameters. For comparison with manual tests, the average difference is only 0.1.

For mobile application evaluation, we conducted the questionnaires for both application design and usability evaluation. Three experts in Information Technology field were asked to evaluate the application design and ten users assessed the usability of the application. 5-Point rating scale is used for our evaluation. The evaluation results are shown in Table II

(a) Sensor No.1

(b) Sensor No.2

Fig. 6. Sensors installation.

TABLE I
THE AVERAGE DIFFERENCE OF MEASUREMENTS BETWEEN TWO SENSORS FROM 23/10/2020 TO 24/11/2020.

Parameter	Number of records	Average difference value
Dissolved oxygen	9,999	0.3098
pH level	10,045	0.6972
Water temperature	10,488	0.6936
Turbidity	10,482	0.1679

V. CONCLUSIONS

In this work, real-time water quality monitoring and notification system for aquaculture are presented. The system is use to monitoring Dissolved oxygen, Temperature, Turbidity, pH level of water using IoT technology. The Arduino Nano is used as controller unit to read the analog values from the sensors. Serverless IoTs is created using Firebase Real-time Database (RTDB) and ESP8266. The experiment has been conducted at Faculty of Fisheries Technology and Aquatic Resources, Maejo University. The proposed model was successfully implemented and tested. The mobile application provided a technological solution that would monitor the water quality in real time. Moreover, it is flexible, easy to operate and install in both iOS and Android operating system. In future work, we aim to expand our system to agriculture and industrial use.

VI. ACKNOWLEDGMENT

This research was supported by National Research council of Thailand and the Office of Agricultural Research and

TABLE II
THE MOBILE APPLICATION EVALUATION RESULTS.

	Criteria	**Average**	**S.D.**
Application Design	Font size	4.33	0.58
	Layout	4.67	0.58
	Color	4.33	0.58
Usability	Ease to use	4.20	0.79
	Speed	3.50	0.53
	Reliability	3.70	0.48
	Scope of information	4.50	0.53
	Notification	3.70	0.67
	Overall	**4.12**	**0.59**

Extension Maejo University.

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