Development of aquaculture water quality real-time monitoring using multi-sensory system and internet of things

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Abstract: Water quality is an important parameter for the health and growth of aquatic species in aquaculture farming system. The threshold values of the water main parameters should be monitored continuously. Contaminated aquaculture water will affect the health, growth and ability of animals to survive. In addition, it will also affect the harvesting yields based on the number and size of the animals. To overcome this problem, the main water parameters, namely temperature, pH, Dissolved Oxygen and Electrical Conductivity are monitored in real-time using a multi-sensory system and the internet of things. Data is acquired by a developed instrument and transmitted wirelessly via a GPRS / GSM module to a web server database. The data obtained are analyzed and monitored through the website and in real-time. Therefore, corrective action could be taken immediately for contaminated water, indicated by water parameters out of range. The system also provides an early signal to farmers based on a specific range of water quality parameters values. This will help farmers make adjustments to ensure appropriate water quality for the aquaculture system.

1. Introduction

The Food and Agriculture Organization of the United Nations (FAO) reported that in 2012, the consumption of aquatic species from aquaculture was almost identical to that of catch from the wild [1]. Aquaculture is a technique for cultivating aquatic animals and is important for food security. This involves the process of cultivating the animal in controlled conditions such as feeding, water quality and disease during the rearing process to increase its growth rate which increases yield. However, due to rapid technological development, increasing demand, water quality problem, disease, labor shortage and rising food cost, the industry faces critical challenge to increase its productivity [2].

Water quality monitoring is an important aspect of aquaculture system. Traditionally, multi-parametric water measurements are performed manually. If water is suspected to be contaminated, water samples are sent to a laboratory to analyze the contaminants [3]. To ensure water quality and oxygen levels, monitoring should be done periodically to provide a safe and good environment for the animals to grow well.

Each aquatic species has its own preferences of water quality. The main parameters for freshwater aquaculture water quality are Dissolved Oxygen (DO), Ammonia (NH3, NH4+), Nitrite (NO2-), turbidity, pH and temperature [4]. The DO is a key parameter to be monitored and controlled in aquaculture systems [2]. The chlorinated water supply will contaminate the system and make it cloudy. In addition, urine and feces of animals will increase water ammonia, turbidity, pH and temperature [5]. Moreover, water temperature affects the animals’ growth rate and yield because they are cold-blooded species. The pH of water also depends on the temperature and DO [4].

Currently, most water quality measurements, analysis and handling are done manually which is time-consuming. Results generated using manual processes may not be accurate due to human factors such as...
errors during the data acquisition process. Advancements in new sensor technologies, data analysis and automated control could improve water quality monitoring, and as a result it could strengthen the production and farm management [6]. Moreover, the rapid improvement of real-time remote monitoring of water quality systems based on embedded systems and sensor technology is good for aquaculture industry [7]. Therefore, building an affordable and easy-to-operate remote water quality monitoring system for diagnostic contamination based on automated and real-time communication platforms is needed for modern aquaculture systems. This will enable the industry to improve effluent systems, reduce catastrophic losses and labor costs as well as increase animal growth rates and increase yields [8].

The main objective of this paper is to present real-time water quality monitoring using multi-sensory system and Internet of Things (IoT) for aquatic species aquaculture systems. This paper discusses system development, both hardware and software, as well as system prototyping. Real-time monitoring would provide details of main water quality parameters. Data is obtained, analyzed and monitored via the website and in real-time. This would allow immediate corrective action for any water parameters whose values are outside the appropriate range.

2. System Architecture

The system architecture shown in Figure 1 consists of a water quality multi-sensory system and the IoT. The multi-sensory system is used to acquire water quality parameters from the aquaculture system and the IoT will display the data on a website.

![System Architecture Diagram](image-url)

Figure 1. The system architecture.

The developed multi-sensory system is an instrument that measures aquaculture tank or pond water quality parameters. The instrument sensors respond is similar to human taste receptors where electrical signals are transmitted by nerves to the brain. The response of the generated electrical signal will correlate with the parameter value. The instrument as shown in Figure 2, comprises of selected water sensors, microcontroller as embedded controller, electronic circuit, GSM/GPRS communication module and embedded control software. The selected water sensors are Electrical Conductivity (EC), DO, pH and water temperature. The sensors are placed inside a close-fitting sensing chamber to enhance the data acquisition process.

The EC sensor from DFRobot which has a built-in connection that simplifies the interface to the microcontroller is used to measure the ability to deliver electric current by ions in the water. Any contaminants in the water tank will increase the EC value, indicating a change in the salt content in the water. If the EC value is higher than the appropriate range, osmotic water is used to lower its value and if the value is lower than the range, calcium carbonate solutions or salt is used to increase it [9].

The temperature of cold blooded aquatic species follows the tank water where this influences chemical and biological reactions. Thus, the tank water temperature should be controlled and kept at a temperature suitable for the health of the animals so that they can grow well. The water temperature is an important factor for the animal environment, affecting the breathing process, feeding, metabolism, growth, behavior, reproduction, detoxification rate and bioaccumulation [10]. A temperature sensor, the DS18B20 from DFRobot is used to measure the tank water temperature. The sensor output pin is connected via a connector to the analogue pin of the microcontroller. The sensor has an accuracy of ±0.5°C and the operating temperature ranges from -10°C to +85°C.

The measure of acidity or alkalinity of tank water is pH and a pH value of 7 is considered neutral.
Metabolism of aquatic species and bacterial nitrification contribute to acid formation in aquaculture farms. A large number of animals can tolerate pH between 5 to 10, and the pH of most aquatic species ranges from 6.5 to 8.5 [11]. The system was developed using a pH sensor from DFRobot and the pH of this sensor ranges from 0 to 14. The system has an accuracy of ± 0.1 pH and the operating temperature range between 0 to 60°C.

DO is the most important parameter in the breeding process that determines the growth rate and yield. Aquatic species require oxygen for respiration depending on type, size, temperature, food and movement. The amount of oxygen that can be dissolved (saturated) in water also depends on temperature and salinity level [11]. The system was developed using the DO Galvanic Probe Sensor from DFRobot and the sensor ranges from 0 to 20 mg/L with an output voltage ranging from 0 to 3.0 volts.

A signal conditioning circuits is used to regulate the instrument sensor output signal before being acquired by an embedded controller. The circuit consists of a biasing network and a voltage follower as an amplifier with unity gain, high input and low output impedance. The impedance matching of this amplifier will determine the appropriate measurement range for the sensor output response. A Low Pass Filter (LPF) is used to eliminate unwanted frequencies from the sensor output response.

A DsPIC33 microcontroller from Microchip Inc. selected as the embedded control of the developed instrument as shown in Figure 2. The microcontroller uses 3.3 volts DC to operate which ensure the system low power consumption. The sensor output response will be converted into a digital signal by the microcontroller on-board Analog to Digital Converter (ADC). The keypad is used to select the instrument software menu during operation and utilities. The alphanumeric Liquid Crystal Display (LCD) is used to display the operating status of the instrument, data acquisition, transmission and utility. The developed instrument is powered by a regulated 12-volt DC power supply.

The developed instrument embedded controller is programmed using MPLAB IDE with C30 compiler from Microchip Inc. The software for the instrument control, utilities, data acquisition and cloud transmission processes is embedded in the embedded controller's memory.

The response profile of the sensor is corresponds to the water multi-sensory parameter value. The data is connected to a GSM / GPRS communication module that is transmitted to a SQL data server. The website program was developed using PHP language software to manage the data sent by the GSM / GPRS module in real-time. The data is retrieved by a cloud-based program and analyzed to predict the water quality. The cloud -based system website will display the values of water quality parameters measured using charts and tables in real-time. The program also handles data processing housekeeping tasks where the display is updated periodically. Since this portable instrument can be used by all tanks in the aquaculture systems, workers and farmers will be able to monitor water quality parameter information via the Internet in real-time.

3. Methodology
An experiment was conducted to verify the function and operation of the developed multi-sensory system that correlated with the aquaculture tank water quality. The samples were collected from the Institute Sustainable Agro Technology (INSAT) aquaculture center at University Malaysia Perlis. The tank size is approximately 6.77m × 6.55m × 0.55m and uses the Recycling Aquaculture System (RAS). The RAS filters are clean manually once a week to maintain tank water quality. The sampling process is illustrated in Figure 3 and Figure 4 shows the process flow chart.
The sampling process begins with the instrument sensor is manually dipped into the middle of the tank during the data acquisition process. The water sample was moved in the sensing chamber and allowed to stabilize for one minute. The acquisition process was repeated three times to ensure its repetition. Then the instrument will send the average of the acquired data wirelessly to the cloud SQL data server through GPRS / GSM communication module. Then the equipment is dipped another one minute into fresh clean water supplied by a small tank for the cleaning process.

4. Results and Discussion

4.1 Electrical Conductivity

The EC sensor response is a time series of the waveform profile as shown in Figure 5. The sampling technique is suitable because the data obtained are within the measurement range. The EC measurements of 200 to 280 μSeimens / cm are an acceptable range. This level is needed to maintain the health of the fish as it is an indicator of salinity.
Figure 5. The Electrical Conductivity

4.2 Water Temperature
Figure 6 shows the water temperature taken from an aquaculture tank. The water temperature varies between 24°C to 27.5°C and is in a good environment for growing aquatic species. The water temperature was verified using a laboratory thermometer by placing it in a water tank.

Figure 6. The Water Temperature

4.3 pH
The results for the pH value of the water as illustrated in Figure 7 are in the range of 5 to 7, which is normal. Fluctuations in pH values are the result of changes in the rate of photosynthesis. This suggests that pH levels between 6 and 9 are best for growing animals.

Figure 7. The pH

4.4 Dissolved Oxygen (DO)
Figure 8 shows the DO concentration in an aquaculture tank. The range is from 5 to 8 ppm and is sufficient for the fish to breathe normally. DO levels vary throughout the day where they are higher during the lighting period and lowest in the early morning. The animal experienced stress if the DO dropped below 4 ppm and died when it was below 2 ppm.
5. Conclusion
The results demonstrate that the water quality multi-sensory system is capable of measuring the main components of aquaculture water samples. Instrument sensors that acquire the parameters of EC, water temperature, pH and DO are connected to an embedded controller equipped with a GPRS/GSM communication module. The obtained data are transmitted to the web server and stored in the SQL database. Aquaculture water quality can be monitored for any contaminants in real-time by workers and farmers which can be shared with the authorities. In the future, its functionality can be enhanced by analyzing data using a machine learning system and controlling water from the tank to maintain its quality.

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