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AQUACISION: a multiparameter aquaculture water quality tester and decision support system

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ABSTRACT

The paper presents a multiparameter aquaculture water quality tester with a decision support system. A device was developed to aid aquaculture farmers in monitoring water quality parameters and maintaining or achieving optimal levels by suggesting ways on how a farmer can respond to such measurements. The AQUACISION device measures six different water quality parameters; temperature, practical salinity, pH level, total dissolved solid (TDS), oxidation-reduction potential (ORP), and algae density. Measurements were sent to the AQUACISION application where they were processed to determine the course of action that was best to maintain or achieve optimal levels using fuzzy rules. Based on the comparative result, the AQUACISION was accurate in measuring temperature, practical salinity, pH level, TDS, and ORP during the actual testing. The application also received an excellent rating on the ISO/IEC 25010 software quality model standard.

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1. INTRODUCTION

Real-time monitoring of water quality parameters in aquaculture is very important to avoid water pollution. Parameters such as temperature, pH level, dissolve oxygen, salinity, electrical conductivity and algae density provides aquaculture suitable environment to grow [1]-[4]. Poor management of these parameters leads to water pollution. Moreover, aquaculture pollution is caused by excess use of fertilizers, uneaten feed pellets and application of other chemicals. Both the fertilizer and feed pellets contain nutrients which if not controlled may cause pollution. Chemicals like lime alters water quality; it increases both the pH level and water hardness, excessive use of such chemical may result to fish kills as fishes live in certain pH level [5]-[7].

To avoid water pollution, there is a need for better decisions and aquaculture management actions. Decisions to be administered must be established from the current aquaculture water quality parameters [8], [9]. Over the past years, there has been a sufficient number of researches made to test the current water quality and the relationship of water pollution with poor aquaculture decisions and actions [10]-[12]. A research conducted for monitoring water quality using wireless networks suggested that conventional monitoring process of manual collection of samples and laboratory testing and analysis are time-consuming and ineffective. In turn, it was proposed that wireless sensors are more efficient in monitoring water quality [13], [14]. Another research introduced a smartphone-based embedded system designed to measure different water quality parameters in various remote locations [15]-[17] Research on multi-parameter integrated water quality sensors offer a low-cost system for water monitoring [18], [19]. Some of the studies conducted on water quality monitoring used wireless sensor network to monitor and control multiple sensors that are connected via Zigbee [20]-[22] using multiple sensors needs different quality of services since it caters to multiple data priorities [23]-[25].

The research aims to build a device that measure different water quality parameters for aquaculture and provide decision support system. The paper focuses on the pH level, electrical conductivity, temperature, algae density, turbidity of the water, total dissolved solid (TDS), and oxidation-reduction potential (ORP) parameters of water. The paper also comes with an application for the decision support system. The application suggests action constructed from fuzzy logic according to the results of the measured water quality sensors.

2. RESEARCH METHOD

2.1. Block diagram of the AQUCISION

The device is consisting of a microcontroller, pH sensor, TDS sensor, ORP sensor, electrical conductivity sensor, temperature sensor, LEDs, photodiode transimpedance circuit, bluetooth module, 2-channel relay modules and toggle switches as shown in Figure 1. The microcontroller is the brain of the device. It controls all the processes and activities the device will perform. The toggle switches with light-emitting diodes (LED) indicators starts the device when set to on and stops the device when turned off. The decision support system will generate suggestions according to the read results from the pH sensor, electrical conductivity sensor, temperature sensor, TDS sensor, ORP sensor and in situ fluorometer. The six sensors will measure six different water quality parameters necessary in aquacultures.

The blue LED and photodiode transimpedance amplifier comprise the in situ fluorometer used to monitor the algae biomass density. The bluetooth module is used to create a connection with the device and the application for sending of measured parameters for decision generation. The 2-channel relay modules are used to switch between devices in queue of measuring. The application will generate suggestions on actions an aquaculture farmer should take to improve production, utilize resources, or mitigate water pollution. Decisions generated will be displayed together with the sensor measurements in the application.

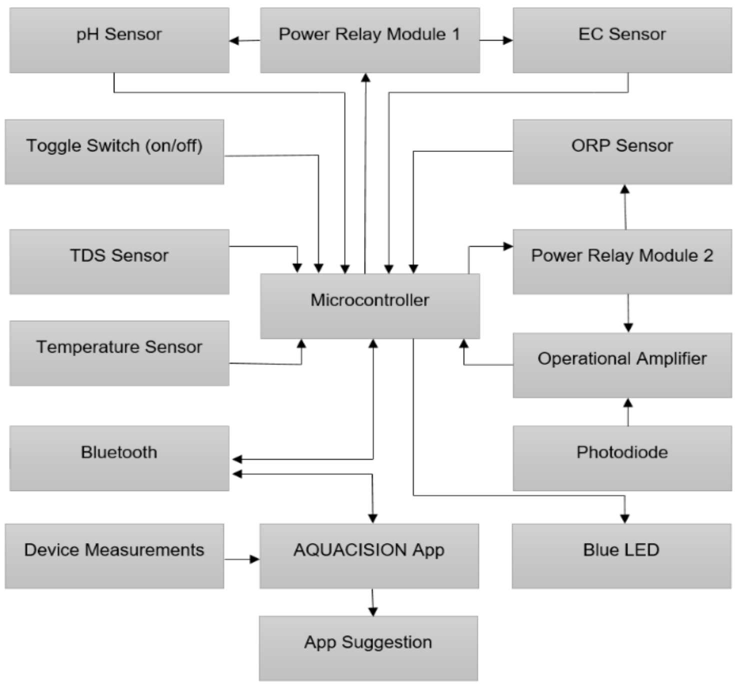

Figure 1. Block diagram of the AQUACISION

2.2. AQUACISION application

The AQUACISION application shown in Figure 2 is created using Android studio. It supports Graddle-based builds and provides an android virtual device to test and debug the applications. The AQUACISION application contains text views to display the measurements sent from the AQUACISION device, to act as labels of each measurements and fields, and to display the generated suggestions based on fuzzy logic. It contains Spinners that creates dropdown menus for the user, list view that allows a list of options to be displayed and sroll views, constraint layouts, and linear layouts for a fixed and arranged display of objects. The fuzzy logic sets are incorporated in the application as well as the creation of bluetooth adapters and threading processes for the application and the device to communicate.

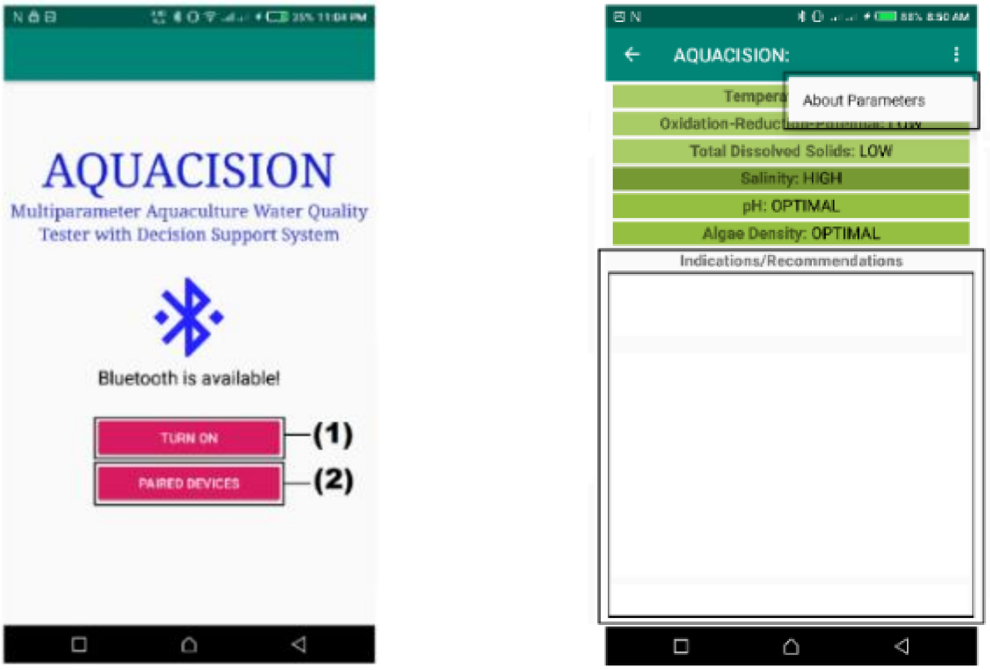

Figure 2. AQUACISION application

2.3. Application evaluation respondents

The AQUACISION application is evaluated by 20 respondents using the ISO/IEC 25010 software quality model standard through a 1-5 rating scale. The 20 respondents are composed of 5 respondents who are new to aquaculture, 5 aquaculture farmers, and 10 respondents who have studied professional fields related to aquaculture. The variety of respondents is to test the overall quality of the application using the sub-characteristics presented in the standard used.

2.4. Testing and evaluation

A. *Percent accuracy (PA)*: The accuracy measures the degree of how close are calculated or measured values to their actual values. The percent error is given as the ratio of error to actual value then multiplied by 100. The percent error is subtracted to 100 to get the percent accuracy. The formula for percent accuracy is given,

$$PA = 100 - \left(\frac{Theoretical\ Value - Measured\ Value}{Theoretical\ Vallue} * 100\right) \tag{1}$$

B. *Average:* Average is the number that expresses the central value in sets of data which is achieved by dividing the sum of all the values in a set by the total number of values in the set. The researchers used this concept to calculate the average of the application survey results. The formula is,

$$Average = \frac{\sum of\ results}{total\ of\ samples} \tag{2}$$

C. *Standard deviation:* The standard deviation measures the amount of dispersion or variation of sets of values. Standard deviations that are low indicates that values tend to be near to the mean of the set, while standard deviations that are high indicates that values are spread out over wider range.

$$Standard\ Deviation = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}} \quad (3)$$

3. RESULTS AND DISCUSSION

3.1. Actual device

The whole device has a measuring part which can be submerged into the aquaculture and a handheld switch part to turn on and off the whole device. The submersible part of the device was made of woods and plastics. This is made waterproof to safeguard the electrical components enclosed inside as shown in Figure 3.

Figure 1. Actual AQUACISION device

3.2. Percent accuracy of different sensors

The computation of percent accuracy of the AQUACISION over the commercial device in terms the different water quality parameters are shown in Tables 1 to 5.

A. *Temperature:* The percent accuracy of the AQUACISION over the commercial device in terms of temperature is shown in Table 1. It can be seen from the table that the device is accurate in measuring the temperature of the different ponds having an average of 99.687%.

Table 1. Temperature test results

Pond Number	Commercial Devices (°C)	AQUACISION (°C)	Percent Accuracy (%)
1	28	28.21	99.250
2	27	27.07	99.741
3	28	28.05	99.821
4	27	27.03	99.889
5	30	30.08	99.733
		Average:	99.687

B. *Electrical conductivity:* The electrical conductivity measures the salinity of the water. The percent accuracy of the device is shown Table 2. It can be seen from the table that the device is accurate in measuring the electrical conductivity of the different ponds having an average of 99.495%

Table 2. Electrical conductivity test results

Pond Number	Commercial Devices (ppt)	AQUACISION (ppt)	Percent Accuracy (%)
1	9.65	9.59	99.378
2	8.87	8.92	99.436
3	8.91	8.94	99.663
4	8.71	8.76	99.426
5	9.32	9.36	99.571
		Average:	99.495

C. *pH level:* The percent accuracy of the device in measuring the pH level of the water is shown in Table 3. It can be seen from the table the device is also accurate in measuring the pH level of the water having an average of 99.298%.

Table 3. pH test results

Pond Number	Commercial Devices	AQUACISION	Percent Accuracy (%)
1	7.01	7.07	99.144
2	8.01	8.09	99.001
3	8.57	8.61	99.533
4	7.97	8.03	99.247
5	9.27	9.31	99.567
		Average:	99.298

D. *Total dissolved solids:* The percent accuracy of the device over the commercial device in terms of TDS is shown in Table 4. It can be seen from the table the device is accurate in measuring the TDS of the different ponds having an average of 99.720%.

Table 4. Total dissolved solids test results

Pond Number	Commercial Devices (ppm)	AQUACISION (ppm)	Percent Accuracy (%)
1	8452	8431.18	99.753
2	9157	9175.33	99.780
3	8651	8677.51	99.694
4	9323	9351.58	99.693
5	7856	7881.22	99.679
		Average:	99.720

E. *Oxidation-reduction-potential:* It can also be seen from Table 5 that the device is accurate in measuring the ORP of the different ponds having an average of 95.587%.

It can be seen from Tables 1 to 5 the comparison of the commercial water quality tester measurements over the AQUACISION device measurements in five different ponds. The computation reveals that the AQUACISION is accurate in measuring the different water quality parameters. Similarly, Table 6 shows the algae density of the different ponds.

Table 5. Oxidation-reduction-potential test results

Pond Number	Commercial Devices (mV)	AQUACISION (mV)	Percent Accuracy (%)
1	100.57	104.73	95.864
2	87.03	91.39	94.990
3	81.23	84.96	95.408
4	71.59	74.01	96.620
5	91.54	96.07	95.051
		Average:	95.587

Table 6. Algae density test results

Pond Number	AQUACISION (ppb)
1	3.51
2	2.89
3	2.35
4	2.07
5	1.54

3.3. Software evaluation using ISO/IEC 25010

The evaluation of the software component of the AQUICISION is shown on Table 7. It can be seen from the Table 7 that the developed software for AQUCISION is excellent in terms of the different characteristics presented by ISO/IEC 25010.

Table 7. ISO/IEC 25010 evaluation results

Characteristic	Average
Functional Stability	4.633
Performance Efficiency	4.667
Compatibility	4.525
Usability	4.750
Reliability	4.525
Portability	4.45
Satisfaction	4.75

3.4. AQUCISION software

Figure 4 shows the interface of the AQUACISION. This is a sample screenshot of the actual testing of the device. The sensor readings were displayed on the AQUCISION software as shown in Figure 4. The software has a view support button to display the decision support based on the sensor readings.

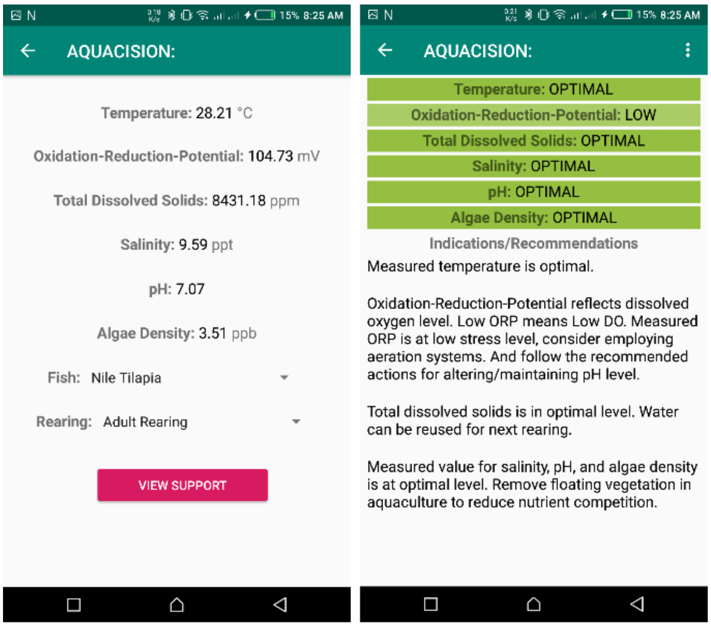

Figure 4. Sample test of pond 1 - application interface display

4. CONCLUSION

Aquaculture water quality parameter monitoring, and decision support system was proposed to generate decision support mechanism using the device measurements and fuzzy rules to have an aquaculture farming that best utilize farming resources without negatively impacting the environment and improve fish production and environment. The study can be further further improved by integrating artificial (AI) and machine leargin (ML) to forecast the water quality parameter based on the previous data measured by the device.

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