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Proposed Precision Analysis of Water Quality Monitoring Embedded IoT Network

***Abstract**. Regarding the essential need for water in agriculture, water resource conservation is becoming a more critical issue that farming developers will consider. The quality instrument used for water monitoring in Farming is one factor to assist an agricultural section in achieving a high impact on their production. This article is presented the precision analysis of water quality monitoring embedded Internet of Things (IoT) Network whereby the proposed invention is a wireless embedded water monitoring system with multi-sensor. The highlight of a measuring instrument is its precision. This study demonstrates its calibration regarding the positive potential of the hydrogen ions (pH). The procedures of precision calibration are related to programming and actual measurement in several tests. The results found that the pH sensor with IoT communication only has a significantly lower erroneous of 0.77%.*

***Streszczenie**. Jeśli chodzi o podstawowe zapotrzebowanie na wodę w rolnictwie, ochrona zasobów wodnych staje się coraz ważniejszą kwestią, którą będą rozważać deweloperzy rolnictwa. Instrument jakości używany do monitorowania wody w rolnictwie jest jednym z czynników pomagających sekcji rolniczej w osiągnięciu wysokiego wpływu na ich produkcję. W artykule przedstawiono precyzyjną analizę wbudowanej sieci Internet of Things (IoT) do monitorowania jakości wody, w której proponowanym wynalazkiem jest bezprzewodowy wbudowany wieloczujnikowy system monitorowania wody. Najważniejszym elementem przyrządu pomiarowego jest jego precyzja. To badanie demonstruje jego kalibrację w odniesieniu do dodatniego potencjału jonów wodorowych (pH). Procedury kalibracji dokładności są związane z programowaniem i rzeczywistym pomiarem w kilku testach. Wyniki wykazały, że czujnik pH z komunikacją IoT ma tylko znacznie niższy błąd wynoszący 0,77%. (**Proponowana precyzyjna analiza wbudowanej sieci IoT do monitorowania jakości wody**)*

Keywords: IoT, pH, Calibration, water quality
Słowa kluczowe: sieć IoT, jakość wody

Introduction

By far, the increasing extreme climate events caused by climate change and the growing vulnerability of crops caused by the deterioration of the ecological environment, agriculture disasters in China show more abnormal phenomena in terms of suddenness, uncertainty, sustainability, and intensity, and crop disasters show a trend of high frequency, high intensity, and increasingly severe harm [1, 2]. Agriculture has been conducting many revolutions, whether the domestication of animals and plants a few thousand years ago, the systematic use of crop rotations, and other improvements in farming practices a few hundred years ago. Smart farming is no single technology. It integrates data and communication technologies into an agriculture production system. [3, 4].

In this study, the proposed prototype of water quality analysis brings in a prototype to apply in prawn farming. The case study at an outdoor prawn farm monitored water quality parameters such as dissolved oxygen (D.O.), pH, and temperature values to maintain the overall health of a prawn farm pond. Moreover, extreme changes to these parameters can have adverse effects during the grow-out period. At the very least, they can limit prawns and reduce the final yield of prawns harvested. The worst case can cause total prawn mortality and high costs [5, 6].

Water is an essential natural resource that has been useful for all Farming, including agriculture and fishing farms. But the water resources are affected by the rapid development of crowded communities, and numerous human activities speed up the contamination and deterioration. This prototype is aimed to ensure that the water quality is maintained or restored to the desired quality level. It needs to monitor regularly because water quality monitoring assists in evaluating the nature and extent of pollution control required and the effectiveness of acceptable pollution control measures. The host station will operate in real-time, and the central station can access information data with real-time monitoring using Internet of Things (IoT) communication [7, 8, 9].

Proposed IoT-Water Quality Monitoring Diagram

The embedded artificial intelligence enabled by the global system for mobile communications for smart farming of water quality analysis system works as a measuring system, which provides information about the biological value of some variable being measured. This work presents that a measuring system consists of several elements in the individual block in more complex measurement situations [10].

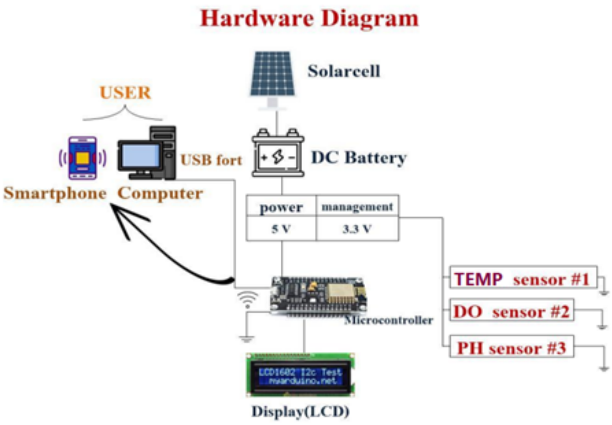

Fig.1 Proposed IoT-water quality monitoring diagram

Figure 1 presents the compositions of the proposed multi-sensing system in this enabled study using a global system for mobile communication (GSM) network for water quality analysis. In the first block diagram, multi-sensors provide an output that functions the pH, D.O., and temperature measurements. A pH sensor is approximately linear. The signal conversion sector provides the output variable and will be transferred to the central processing unit conveniently. This Section needs to convert an input sensing voltage by a bridge circuit known as a transducer.

The signal processing unit uses to improve the signal quality of the output of a measurement system. Namely, this unit amplifies the primary transducer sector's output signal and the sensing process's sensitivity and resolution.

An essential point of the proposed system is information utilization. The implementation omitted an automatic control scheme and transmitted a signal-fed direct control system. The proposed water quality analysis consists of the main component in Figure 1.

Besides the core feature of Wi-Fi and Internet network communication, the IoT-water quality monitoring system module. The onboard SIM800L GSM module can communicate with the ESP32 microcontroller via SMS or phone call, then the user's smart device can connect it to the internet using SIM Card with an internet data plan. The embedded enabled with the global system for mobile communications for smart Farming of water quality analysis is a novel development module applying IoT projects that can be used where getting Wi-Fi router access is unavailable and can be managed by sending a piece of information using a short message service (SMS). Thus, this can be considered another option to not lost a connection between the end device node and users [11].

A sensor is a transducer device that detects events or changes in its environment and then provides a corresponding electrical output. The most important characteristics of a sensor are precision, resolution, linearity, and speed. This article highlights performance to accuracy by calibrating whereby to remove structural errors. The embedded AI-enabled with the global system for mobile communications for smart Farming of water quality analysis consists of three primary sensors, which are 1) dissolved oxygen sensor, temperature sensor used underwater, and 3) pH sensor. A pH sensor can measure flow and how acidic or basic alkaline the water is. It is defined as the negative log of logarithmic and goes from 0 to 14 level. It is low for acidic and high for alkaline solutions. A natural source of water pH is around 7. With each increase in pH, the hydrogen ion concentration decreases ten-fold, and water becomes less acidic. A pH sensor has to measure the Electrode and a reference electrode. A battery-positive terminal is connected to the fixed potential, and when the pH sensor is immersed in the solution, the reference electrode ion concentration. The differential voltage of electrodes changes with the temperature; therefore, a temperature sensor is also necessary to current the shift in voltage [11].

Calibration Test Methodology

Calibration of a measuring instrument is the process of confirming the accuracy of the measuring device by testing the tool in the laboratory by an experienced expert, which is necessary to verify that the Value of the measuring device is always correct. The reason to calibrate the measuring instruments prototype of the proposed embedded AI-enabled of water quality analysis is that all kinds of instruments will be changed and errors when used for a while. Thus, there is an expectation of the outcome, deterioration, and variations over time due to various environmental conditions, such as temperature, electricity, chemical or mechanical, etc. In addition, the user of the measuring instrument must always be aware that deterioration of measuring devices can also occur through use and storage.

When the measuring device is in such condition, it causes inaccurate from the original Value. As a result, the measurement results are unreliable and affect the quality of various industrial plants that use scales for raw material weighing or products produced and then prepared to pack [12]. Hence, the components in the calibration of measuring instruments that are defined in the ISO/IEC 17025 standard consist of 4 main parts, which are;

1) Reference standards equipment
2) Appropriate calibration method
3) Environment of the calibration laboratory, and
4) personnel

1. pH Calibration Setup

In this calibration, the AI-Enabled with the GSM technologies of water quality monitoring analysis refers to the reference standard for calibrating the pH sensor measuring instrument.

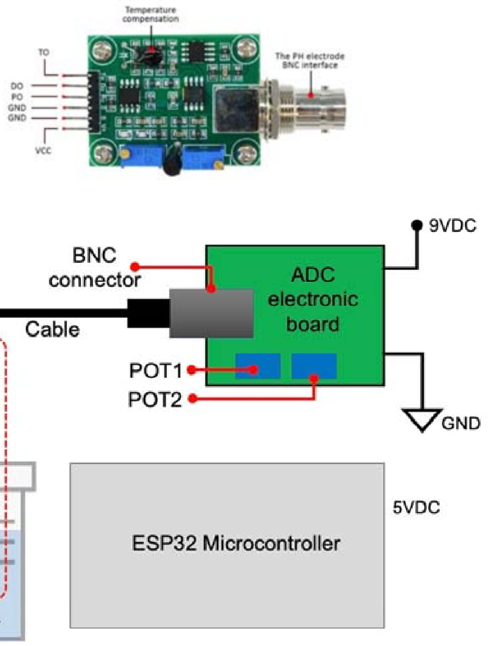

Fig.2 Pinout features of embedded IoT-pH sensor

Figure 2 presents the Pinout features of the pH sensor probe module, which are consisted of the following pins.

TO – Temperature output
D.O. – 3.3V output pin (from pH limit Potentiometer)
P.O. – pH analog output pin
GND – Ground for pH probe
GND – Ground for board
VCC – 5V DC
POT 1 – Analog reading offset (nearest to Bayonet Neill-Concelman (BNC) connector)
POT 2 – pH limit setting

Thus, out of these seven pins, they only used three pins; Vcc, G, and Po.

pH Limit: This potentiometer is to set a limit value of the pH sensor circuit that causes the red L.E.D. to light up and the D.O. Pin signal to turn ON.

After reviewing the pinout features of the pH sensor probe, the calibration setup procedures are processed as follows.

Number equations consecutively with equation numbers in

In this article, the pH sensor's calibration is analyzed. There are two potentiometers in the circuit which it's closer to the BNC of the probe is the offset regulation; the other is the pH limit. More details are explained as follows.

Offset: The average range of the probe oscillates between negative and positive values. The 0 represents a pH of 7.0. To use it with Arduino Microcontroller Families circuit, which added an offset value to the Value measured by the probe. Thus, the Analog to Digital Converter (A.D.C.) samples positive voltage values. Namely, the force of a pH value at 7.0 by disconnecting from the circuit and short-circuiting the BNC connector with the outside pin. Measure the P.O. pin's Value with a multimeter and adjust the potentiometer to 2.5V. The offset potentiometer is used to change this so that a pH = 7 will read the expected 2.5 V to the microcontroller analog pin. The analog pin can read voltages between 0 V and 5 V; hence the 2.5 V that is halfway between 0 V and 5 V as a pH =7 is halfway between pH 0 and 14. Moreover, the efficiency percentage (slope of linear graph) should be acceptable at 95% to 105%.

The pH sensor calibration programming is a basic program that will be used to calibrate the pH sensor interface circuit. This program aims to read analog output pin Po and display the voltage on the serial monitor. The correct communication port is selected before verifying and uploading software programming into the microcontroller. After that, continue to upload and wait until the program has been wholly uploaded.

After connecting equipment according to the pH sensor probe module features, the controller board will be shown the blue L.E.D. on board "ON." Then, upload the programming code to the controller. Before bringing the pH sensor prototype to other water tests, the primary basic test is to put the pH electrode into the standard solution whose pH value is 7.00 and directly short the input of the BNC connector. The error from the pH calibration test should not exceed 0.5 by comparing it with 7.0, and the difference value should be changed to the "Offset" in the sample code. In the results tested, the pH printed is 7.02, and the difference is 0.02. Then, the code is changed from "#define Offset 0.00" to "#define Offset 0.02" in the programming software.

Experimental Results

Again put the pH electrode into the standard pH solution whose exact pH value is 4.00. Wait a minute to adjust the potential gain device; the tested pH value stabilizes at around 4.00. The acidic calibration has been completed, and the pH sensing prototype can measure other water samples.

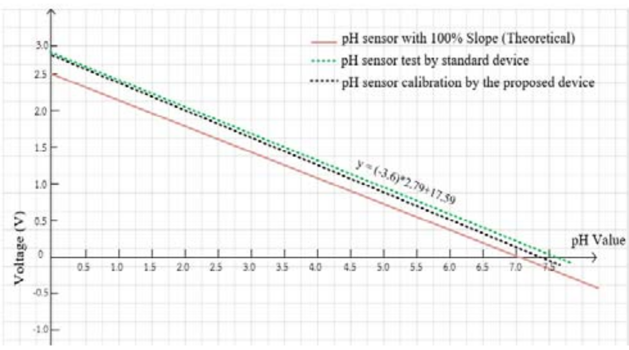

Fig.3 The results of pH plotted based on individual module tests

In addition, Figure 3 presents the pH sensor calibration transformed into a graph form. The water used for testing the pH sensor calibration is in the prawn farm by the standard pH measuring device (reference device). The average pH result is 7.55, collected ten times tested. On the other hand, the prototype also tested the pH calibration using the same water source. The average pH result is 7.4 value. Two equation lines are plotted (black dotted line and green dotted line) to compare the slope (% effectiveness) with the theoretical line (solid red line).

The procedure used to calibrate the voltage conversion that will give the pH sensor. Thus, two pH reference values are needed to measure the voltage returned by the sensor on the pin Po. Suppose the voltage value is over 2.50 V, which can use the trimmer to adjust this Value. Usually, the pH value is from 0.0 to 14.0 of 7 means 2.5 V. Thus, a voltage of 2.5 V is to be set by using a trimmer, which is now the Value will be shown the Value set of 2.5 V. The prototype's pH sensor is now calibrated.

According to the individual several times tested, the results were calculated in an average value to be an accurate value to calibrate the pH value and demonstrated by plotting in a graph according to Figure 3. Therefore, the equation of calibration pH sensor is compared by measuring test between the ranges of pH value from 4.01 to 6.86, and the Pin voltage measured values are between 3.04 V to 2.54 V. Therefore, the offset pH value equal to 7.0 will be received the voltage comes out as in equation (1) at the temperature of 28.51 °C:

(1) $$x = (2.54 * 7.00)/6.86$$

The voltage measured from the output P.O. pin is 2.591 V.
The %efficiency (reference slope) is equal to -5.76;
In case, the pH value measured is 7.55,
therefore;

(2) $$x = (2.54* 7.55)/6.86$$

The expected voltage value measured from the P.O. pin is 2.79 V, at an under-water temperature of 28.54 °C
Therefore, the linear equation is;

(3) $$y = m(2.79\ V) + b$$

since, pH = 7.55;

$$7.55 = m(2.79\ V) + b;$$

Thus, the % efficiency is equal to -5.76 V

$$b = 7.55 – (-16.07)= 23.62$$

∴ The linear equation appears as in equation (4)

()4) $$y = (-5.76)*2.79+23.62$$

The pH sensor's linear equation of standard device is;

(5) $$y = (-3.6)*2.79 + 17.59$$

The proposed calibration compares working standard devices as much as possible at appropriate time intervals against instruments of higher accuracy. The instrument calibrating working standard instruments is known as a secondary reference standard. Therefore, it must be a well-engineered instrument and refers to the theoretical linear equation that gives high accuracy and is stabilized against drift in its performance with time [13].

This sub-section aims to demonstrate the embedded pH-measuring prototype of water quality analysis. More details are tableted as in Table I below.

The results and discussions of the embedded IoT-water quality monitoring have been presented. The main point mentioned in the previous Section is the pH sensor calibration in individual theory to close the reliability compared to the standard of the Digital pH Meter SP01 model. Namely, the pH measurement and temperature parameters are considered in this Section, and the tests are divided into different water types by calibration system as shown in Figure 4.

(a) Proposed IoT-water quality Monitoring (b) Standard pH-device
Fig.4 Comparison pH-test of both systems

Table I. Sampling test of pH value of both systems

No.	pH-Test Value		
	Proposed IoT-water quality monitoring	Standard pH device	Different (%)
1	7.40	7.54	1.86
2	7.41	7.55	1.85
3	7.42	7.54	1.59
4	7.41	7.56	1.98
5	7.39	7.56	2.25
6	7.37	7.57	2.64
7	7.40	7.56	2.12
8	7.37	7.58	2.77
9	7.45	7.59	1.84
10	7.45	7.59	1.84
Average	7.41	7.56	2.08

Table I concludes the experimental results collected from the water pH testing of the prawn farm. The pH testing was repeated ten times, and the average value was calculated using the pH sensing prototype and a standard pH device (SP01).

The prototype's average pH value and standard deviation (S.D.) are 7.41 and 0.279, and the SP01 device is 7.56 and .018, respectively. Therefore, based on the results, the comparison found that the faulty percentage unit is 0.77.

Conclusions

This article presents information tested on embedded IoT-water quality monitoring in the part of pH calibration. The results show the precision of the proposed IoT-water quality monitoring system with erroneous less than 0.77%. In future works, authors have planned to demonstrate other performance issues, such as oxygen, and temperature parameters, which they can analyze in deeper detail further.

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