TEST Engineering & Management
March - April 2020
ISSN: 0193-4120 Page No. 8010 - 8016

Design of Miniature Ship for Measuring Quality of Water Using Modified Fuzzy

YorizaAfisaTarigan[1],UnangSunarya[2],AtikNovianti[3]
[1,2,3]Telkom Applied Science School Telkom University Bandung, Indonesia.
[1]yorizaadalagi@gmail.com,[2]unangsunarya@telkomuniversity.ac.id,[3]atiknovianti@telkomuniversity.ac.id.

Article Info
Volume 83
Page Number: 8010 - 8016
Publication Issue:
March - April 2020

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 09 April 2020*

Abstract

Water is one of the most important elements in life. All living things need water as well as human being. This paper addressed the design of miniature ship consisting pH, temperature, and turbidity sensor. These sensors have function to sense parameters of water that could be used to determine the quality of water. The experiment used Arduino Uno as a device to process the output of sensors. A modified fuzzy method has been applied to classify 3 of qualities water: unsafe, safe, and worthy. The results of the classifier fuzzy then would be sent to cloud service named Geeknesia. Utilizing cloud service Geeknesia, the ship could be controlled and monitored wirelessly using esp8266 interface. The MQTT protocol has been used as communication protocol between controller and cloud server to send the data and command. Based on single experiment sensor, our design ship could measure pH with accuracy of 100% after calibration, 98.92% of temperature and turbidity 0-50 NTU with 1.68 seconds average delay during monitoring process. Overall, our implemented method could classify the quality of water through sensed parameter very well..

Keywords; *miniature ship, pH, temperature, turbidity, fuzzy, esp8266, Geeknesia*

I. INTRODUCTION

In recent, the need for clean water has been increasing. This is caused by the increasing of water pollution. Many researches related to water quality have been done to help people get clean water. Assessment of quality water for drinking water has been conducted in [1]. In this experiment, water supplies from open well, river, and lake throughout the village were sampled. The sampled water has been analyzed based on physical-chemical and microbiological quality to determine whether the water is safe for drinking or not. In [2][3], a research review of water assessment has been done to assess the quality of water based on parameters that acquired from sensors, including temperature, pH, turbidity, salinity, nitrates and phosphates. The study of quality water could be described using water quality index, Horton index and Dinius index [4][5]. Those 3 assessments index were used to determine whether the water has been negatively affected by pollutants or not. Water Quality Index (WQI) also has been utilized considering the minimum, maximum and mean annual values of biological, chemical and physical parameters of water [6]. Identification and assessment quality of drinking water has been conducted using classification and regression tree method in [7]. In this study, the potential impact of water quality was investigated for better understanding. The quality of water was classified and then predicted. At the end, decision model making applied for testing the class of water quality.

In this study, proposed the assessment method based on modified Sugeno fuzzy model to classify the quality of water into 3 classes: worthy, safe, and unsafe. The 3 classes described water could be used for consumption, other than consumption and not both because of hazardous. The experiment has been

March - April 2020
ISSN: 0193-4120 Page No. 8010 - 8016

conducted using mobile miniature robot, similar to [8][9]. The robot was equipped with 3 sensors to sense the used parameters for identifying quality of water. Bidirectional communication was used to control and monitor the robot. The robot was controlled wirelessly using the embedded esp8266 interface on microcontroller connected to cloud service www.geeknesia.com and the decision of class quality of water as an output of fuzzy logic was sent to cloud service. Modified fuzzy model Sugeno implemented for classifying the quality of water as state of the art and used MQTT protocol for managing the communication between controller and server for measuring the quality of water in Toba Lake, North Sumatera. Related researches to monitoring water quality control using wireless devices have been done in [10][11]. The most similar one to our study has been conducted in [12][13][14]. In this wireless monitoring study used Internet of Things (IoT) system but without fuzzy classifier like in our method. Beside that in [15] also study about monitoring system of water quality but using Wireless Sensor Network.

This paper was organized into four sections: Section 1, introduction. Section 2, method implementation, Section 3, results and discussion, and the conclusion of experiment in the last section.

II. MODIFIED FUZZY MODEL

Modified model of Sugeno fuzzy logic implemented as classifier in this paper. This method was used to classify the quality of water to be 3 classes. This method composed of 3 parts: fuzzification, rule of inferences and defuzzification. In fuzzification, the real values of pH has changed into value between 0 and 1. In Fig. 1, the acidity of pH divided into 3 parts and its range, they are: acid 1-6, neutral 5-9, and base 8-14 respectively.

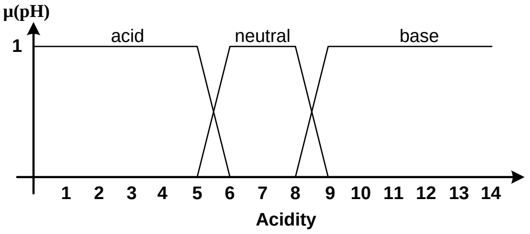

Fig. 1. Degree of membership pH

Fig. 2 below shows the degree of membership temperature. For this case, temperature divided into 3 parts cold with the range 0-32, normal 28-50, and hot 48-80 respectively. This range based on the capability of sensor to read the value of temperature. Because of tropic area, assumed the minimum value of surface water of Toba Lake was 0° Celsius and the maximum 100° Celsius.

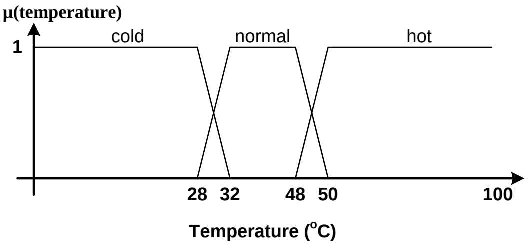

Fig. 2. Degree of membership temperature

Fig. 3 describes the degree membership of turbidity. Turbidity shows the water status related to the value of turbidity. It is commonly used ppm (part per million) to show the level of turbidity. The lower of turbidity value the purer the water, and vice versa.

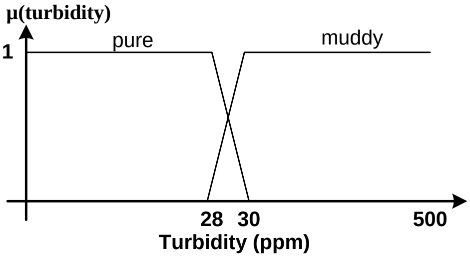

Fig. 3. Degree of membership turbidity

After fuzzification process, the next step is determine the rules for filtering the output of fuzzification based on 3 conditions of sensor simultaneously during sensing process.

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March - April 2020
ISSN: 0193-4120 Page No. 8010 - 8016

Rules of inferences

pH	Temperature	Turbidity	Decision
Acid	Cold	Pure	Unsafe
	Normal	Muddy	Unsafe
	Hot	Pure	Unsafe
	Cold	Muddy	Unsafe
	Normal	Pure	Unsafe
	Hot	Muddy	Unsafe
Neutral	Cold	Pure	Safe
	Normal	Muddy	Worthy
	Hot	Pure	Safe
	Cold	Muddy	Worthy
	Normal	Pure	Safe
	Hot	Muddy	Unsafe
Base	Cold	Pure	Unsafe
	Normal	Muddy	Unsafe
	Hot	Pure	Unsafe
	Cold	Muddy	Unsafe
	Normal	Pure	Unsafe
	Hot	Muddy	Unsafe

The last processing is defuzzification. Based on result of rules inferences defined before. This process recalculated the real value of the output method and then classified based on each class. In this part, modified the fuzzy method used to fit the rules inferences by trying and error. This modified has been done based on calibrating all the 3 sensors compared to results of measurement using reference devices to get higher accuracy of measurement.

III. DESIGN MODEL

This section describes detailed design system of mobile miniature ship including diagram block of system robot and flowchart of monitoring and controlling system robot.

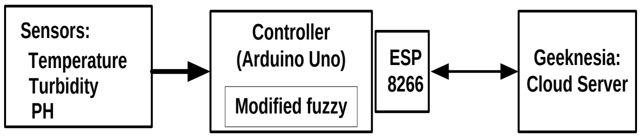

Fig. 4. Block diagram system robot

Fig.4 illustrates block diagram system miniature robot consisting main controller Arduino Uno. This controller has a function to control all process happened during monitoring and controlling robot. The controller read analog value of sensors using ADC feature embedded on it. Using this ADC feature the analog values of sensor were converted into digital values then processed by the main processor. This digital value of sensor then fed into the modified fuzzy method to be classified as safe, unsafe or worthy condition of measured water. The output of the fuzzy method was sent to cloud server Geeknesia via esp8266 interface and could be monitor via personal devices such as personal computer, laptop or even handphone. The connection between microcontroller and cloud server is bidirectional connection. In addition to monitoring sensors output, this connection is available to send commands to control the movement of miniature ship. The detailed of working system robot could be seen in Fig. 5 as follow.

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March - April 2020
ISSN: 0193-4120 Page No. 8010 - 8016

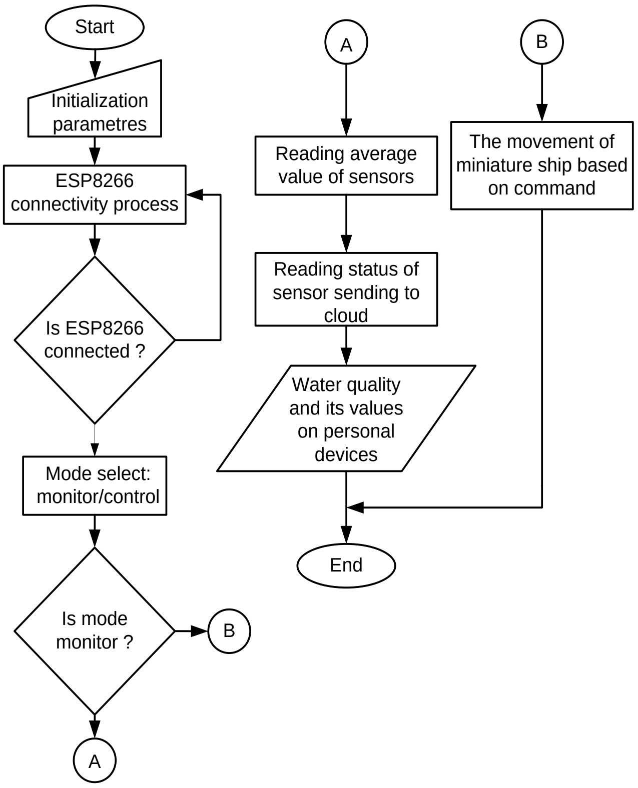

Fig. 5. Flowchart of robot work system

Fig.5 shows flowchart how the process of robot sending information status of water to cloud server and controlling the miniature ship robot based on command sending by user through esp8266 interface.

IV. RESULTS AND DISCUSION

The results of implemented method has been evaluated part by part and at the end evaluate all together.

Calibrating pH sensor

pH sensor	**References**	**Accuracy (%)**
4.20	4 (acid)	95.00
4.21	4 (acid)	94.75
4.22	4 (acid)	94.50
7.35	7 (neutral)	95.00
7.37	7 (neutral)	94.72
7.37	7 (neutral)	94.72
7.11	7 (neutral)	98.40
9.02	9 (base)	95.00
9.02	9 (base)	95.00
9.01	9 (base)	98.80
Average		**95.56**

Table 2 shows the comparation results of pH sensor equipped in miniature ship and references with the average value of accuracy 95.56%. This is quite high accuracy but still need to be optimized for better accuracy. For this reason, need optimized the algorithm by rounding the value measurement of sensor to the nearest value from floating value to integer value. By converting this type of data will get perfect value of calibrating.

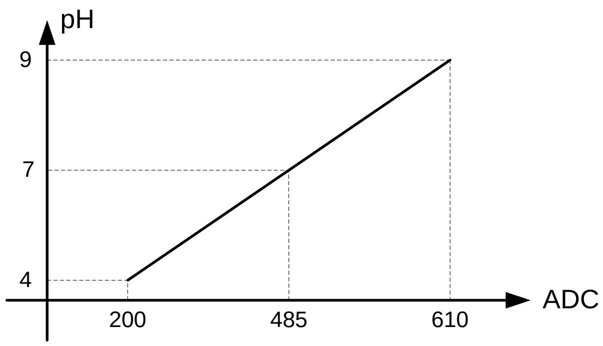

Fig. 6. Calibrating pH values based on ADC values

Fig. 6 illustrates calibrating values of pH sensor based on values of ADC reading by sensor. The value of pH should fit to the capability of sensor reading the data. By this way the value of ADC would fit to the 14 value of pH. For this experiment, all the 14 values of pH have been sample with only 3 values of pH i.e. 4, 7, and 9 and the final equation for the calibrated value of pH could be seen in (1).

$$pH = 0.012\,ADC - 6.43 \quad (1)$$

After calibrating process, obtained accuracy of

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March - April 2020
ISSN: 0193-4120 Page No. 8010 - 8016

calibrated values pH sensor is 100%.

Turbidity sensor measurement

ADC value of Turbidity Sensor	Turbidity Sensor	Certificates of NTU
368	0	0
286	500	700
263	500	1230
215	500	2130

In this paper also calculated the value of turbidity sensor as shown in Table 3. First, the turbidity sensor was tested to mineral water that has value almost zero. This indicated that the mineral water is pure. Another test was used for mixing water with coffee powder to get muddy water from second test until the final one.

After adding coffee powder, the value of turbidity sensor showed the maximum value of 500 ppm. This indicated that the status of water has been changed from pure to be muddy. When compared to NTU certificates with the different value of ADC (Analog to Digital Converter) the output turbidity sensor remains same 500 ppm for muddy condition. This values as results of the restricting value that defined in fuzzy model that the maximum value of turbidity must be 500 ppm.

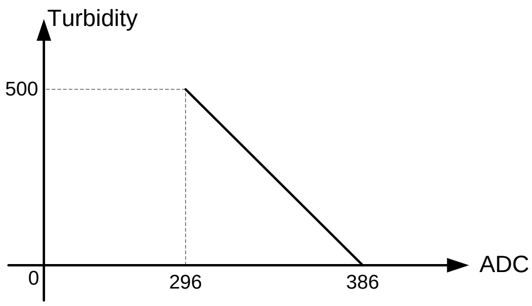

Fig. 7. Calibrating turbidity values based on ADC values

Fig. 7 describes the calibrating process for turbidity values after sampling the digital values of turbidity sensor. In this experiment the turbidity sensor could read value of turbidity in range 0-500 ppm (part per million). After sampling the digital value of sensor, plot the value of turbidity with respect to value of ADC. From this plotting can used simple linear regression to calculate the optimal equation that could be represent other value of ADC. The final equation from this calibrating process could be seen in (2) as follow.

$$Turbidity = 5.55\,ADC - 1644.4 \qquad (2)$$

Using the calibrated turbidity equation could increase the accuracy of reading sensors based on reference.

The output of temperature sensor also calculated and calibrated to references. From this comparation, the error between the output of temperature sensor calculated and the reference and the results could be seen in Fig. 7 as follow.

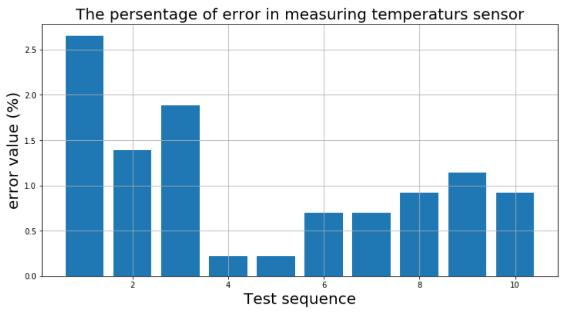

Fig. 7. Percentage error during measurement

Fig. 7 above illustrates the error measurement after compared to reference from 10 times measurement and the average of error is 1.074%.

When testing all together as system, 100% accuracy of testing modified fuzzy logic reached. This value based on comparation the output fuzzy related to defined rules that have made before in rule of inferences. All the system has word perfect both controlling and monitoring system. This system worked well, because not only recalculate all the

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process after calibrating all sensors based on references used, but also optimized the error from the first one before calibrating done.

Time delay during controlling and monitoring respond from and to cloud server also calculated. During monitoring process, average delay is 1.68 seconds. This delay was counted from the experiment in which user press the button on keyboard computer until the miniature robot make movement during controlling robot.

Respond delay of command

Sequences of testing	Delay (second)
1	1.3
2	1.8
3	1.7
4	2.1
5	2.7
6	1.9
7	1.4
8	1.6
9	1.3
10	1.0
Average	1.68

Delay for any command that sent from personal device to miniature ship robot through esp8266 interface also calculated. This calculation has been done 10 times to get average value of delay. This measurement showed that our design miniature robot could work properly based on command received prom the user with minimal time delay parameter. Overall, our implementation of miniature ship robot and the implemented method has worked as design. This argument was supported not only by the minimum value of time delay but also by the capability of proposed method modified fuzzy when classifying the quality of water whether safe, unsafe, or worthy.

V. CONCLUSION

In this paper, implementing modified fuzzy to classify 3 input sensors become safe, unsafe, and worthy for determining the quality of water. To achieve best results, calibration process with the reference of each sensor is must than optimized all the error to be minimum value. At the end, retested the measurement based on calibrated results during optimization. By doing this can reach the best results. For communication issue, using MQTT protocol to get best results for communication process between server and microcontroller, the best result for monitoring and controlling with the average delay of 1.68 seconds.

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March - April 2020
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