Review Article

Prototype of Water Turbidity Measurement With Fuzzy Method using Microcontroller

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Abstract: Water is a source of much-needed living things such as daily needs and transportation routes, and also as a source of energy. Water is also essential as a water quality factor. Good water for treating cold-water ornamental fish with temperatures below 20° Celcius has a maximum water turbidity value of 10 NTU (Nephelometric Turbidity Unit); if the turbidity level is above 10 NTU, the water will be declared cloudy and affect fish health. The object of this research is ornamental aquarium fish with the type of goldfish. The research method used is qualitative. The research flow begins with observing the problem, then designing and simulating the Arduino Uno as a place to process the measuring data. The prototype of this tool aims to show changes in the level of turbidity of water from the value of water turbidity. This prototype uses the fuzzy method to assist the testing process. This study's results for five days showed that 1 out of 5 tests indicated that the aquarium water was cloudy, namely on the fifth day. The results of this study are expected to be implemented in a prototype for measuring water turbidity using the fuzzy method using a microcontroller. The design of this water turbidity measuring instrument is expected to estimate the turbidity of water or liquid correctly, precisely, accurately, with a small error rate, and notify warnings for replacing ornamental fish aquarium water.

Keywords: Turbidity Sensor, Prototype, Arduino Uno Microcontroller, Water Monitoring, Fuzzy Logic

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1. INTRODUCTION

Water is the source of the necessities of life for living things that are needed, such as daily needs, transportation routes, and a source of energy. Water is also essential for animals such as fish. Fish have a compassionate nature based on the water they live in. One of them is the goldfish (Carassius auratus), a type of ornamental fish with a distinctive body shape and diverse body colors such as red, yellow, green, black to silvery. Water problems in the care of goldfish ornamental fish are caused by feces, leftover feed, and water filters that cannot filter cleaner water. So that the water media has poor water quality, such as Ph, Turbidity, DO, and Ammonia. From these problems, finding a solution for managing water quality care in goldfish aquariums is necessary. One effort that can be made to deal with this problem is to directly replace the aquarium water at a time and level of turbidity that has passed good water quality in the care of goldfish using a turbidity sensor.

This technology is quite reasonable because this assembled tool's prototype has a small error rate in measuring the turbidity level of goldfish aquarium water. Ornamental fish are a group of cold water fish (< 200 °C) with a turbidity tolerance of 10 NTU. Water turbidity conditions affect the development and health of goldfish because the symptoms caused by water that has water turbidity above 10 NTU will make goldfish become drunk and swim upside down. Therefore, The monitoring process of water turbidity in the goldfish aquarium must continue. Internet of things [1,2,13,14,15,16,17, 39] technology is

developing rapidly to solve various problems or monitor objects or applications or case studies [6,20] to obtain real-time sensor values such as water pH. Sensor data is stored on an application server or cloud [5,9], which can then display data on a graph that can be converted to excel, PDF files, and other extensions for reporting. Even the development is now towards Artificial Intelligence (AI) [8] and is applied to the IoT monitoring system, which turns into AIoT. In addition to website development which also leads to flexibility, WEB has developed flexibly towards e-commerce [12,22,27,29,30,31,32,33,34,35,36], not me IoT, but a centralized WEB system such as GO-JEK, GRAB, etc. in the development of technology AI, AIoT, IoT, Cloud Management, and Website Management, e-commerce, and other applications require an algorithm [21,23,24,25,26, 28, 37] to increase efficiency or effectiveness.

Turbidity describes the optical properties of water, which are determined based on the amount of light absorbed and emitted by the materials contained in the water. Turbidity is caused by solid objects in the form of inorganic or organic materials suspended and dissolved in water. Turbidity in ornamental fish aquarium water should not be more than 10 NTU; a turbidimeter is needed to know how to measure it. Turbidimeter is a standard test instrument used to determine water's turbidity level. The existence of this tool is already familiar and easy to find. However, this tool is only owned by certain parties because the price is relatively high. To test whether the water we have has a standard or not, we have to go to the Water Testing Laboratory; this causes it to be less effective and efficient.

Based on these considerations and reasons, making equipment in the form of a prototype is necessary. Moreover, a tool to measure the level of turbidity of water with the fuzzy method [3,4,7,10,11] and a microcontroller still needs to improve the level of precision. so that it is obtained the water's turbidity level and as a guide for changing the water of ornamental fish aquariums. The sensor used to measure turbidity uses a turbidity sensor. This turbidity sensor measures water quality by detecting the level of turbidity and also detects suspended particles in water by measuring the transmittance and Scattering of light which is directly proportional to the level of Total Suspended Solid (TTS). The higher the TTS level, the higher the turbidity of the water or liquid. This sensor supports two output modes, digital output, and analog output, so that it can be easily accessed via Arduino or other microcontrollers. This sensor can be applied to measure the turbidity of water in rivers, lakes, laboratories, liquid waste, and so on.

2. THEORY

2.1. BLOCK DIAGRAM

The system block diagram is an essential part of the design and manufacture of this tool because, through this block diagram, the working principle of the entire system circuit on the device can be known. The block diagram of the system for measuring water turbidity using Arduino can be seen in Figure 1.

Arduino UNO regulates the general working principle of this tool as the main control. Arduino UNO is connected to the turbidity sensor. The sensor is a module that reads the turbidity value of a liquid that outputs data. The data is to be taken by Arduino Uno and processed into input data for the LCD. The output of the processed data will be displayed on the LCD so that users can find out the turbidity value of the water.

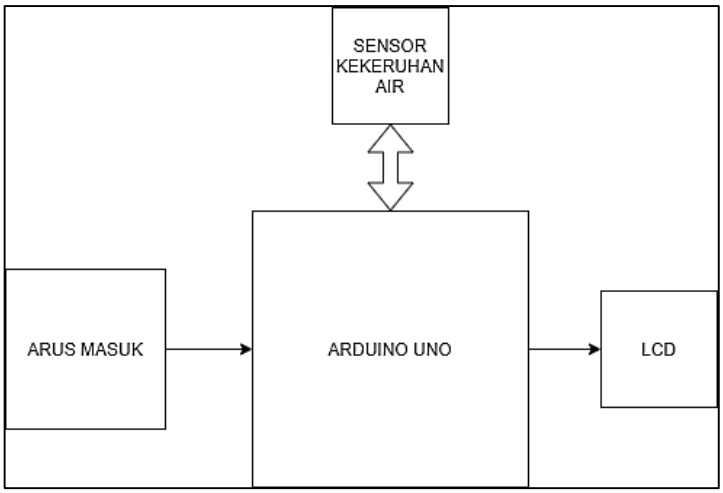

Figure 1. a Block Diagram

2.2. RESEARCH FLOWCHART

This research flow chart is the steps taken to facilitate the research process so that it can run in a systematic and directed manner. The research flowchart is shown in Figure 2.

3. METHOD

3.1. RESEARCH METHOD

This study uses primary and secondary data, including the input variables of a lot of water, light Scattering, and turbidity. This study uses the Mamdani fuzzy method, and the following steps are carried out for research:

a) Carry out secondary data collection activities needed in calculations and analysis.
b) Determine the range and membership function of each attribute
c) Determination of the consequent function for each implication rule
d) Forming fuzzy implication rules by combining each linguistic attribute on each input variable
e) Perform defuzzification by calculating the weighted average of all fuzzy implication rules [18,19,38,40]
f) Affirmation (defuzzy) is the process of confirmation (defuzzification) using the help of software Matlab R2017a using the facilities provided in the fuzzy toolbox.

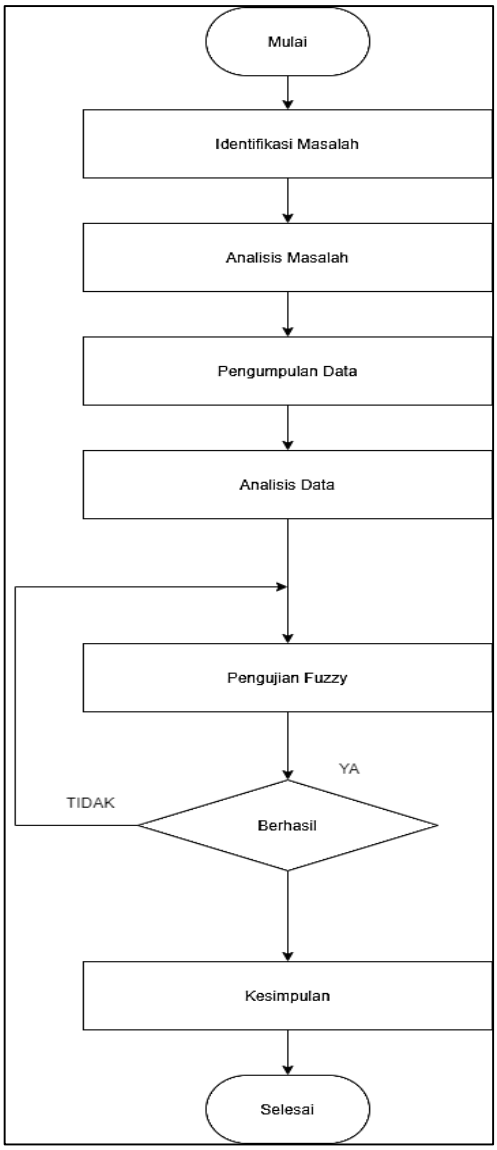

Figure 2. a Research Methodology Flowchart

3.2. PROBLEM IDENTIFICATION

The first step that must be done after obtaining and determining the title of the research is to identify the problems to be studied. The identification referred to in the research is not out of the problem's main objective, so the research's scope is not out of the goal. The main problem under study is the turbidity of water using the Mamdani fuzzy method. The purpose of this system is that this system is expected to make it easier for users to determine the level of water turbidity.

3.3. PROBLEM ANALYSIS

In problem analysis, an analysis of the problems raised in this study will be carried out following the specified problem limits. The analysis of the resulting problem is how to apply the fuzzy logic (Mamdani) to solve the problem of the level of Water turbidity. By analyzing the situation that has been determined, it is hoped that it can be adequately understood.

3.4. DATA COLLECTION

The data collection method used in conducting this research is a literature study. In this method, information is collected by collecting journals related to the topic/title of the study to support the analysis of data and information. Literature sources are obtained from the internet, which discusses Mamdani fuzzy logic, and journals from websites (internet).

3.5. DATA ANALYSIS

This data analysis phase was carried out using the Fuzzy Mamdani method to determine the water turbidity level with predetermined variables, including a lot of water, transmittance, light Scattering, and turbidity.in analyzing fuzzy logic with the Mamdani method, several stages must be passed, including:

a) Define fuzzy variables.
b) In determining fuzzy sets, input and output variables are divided into one or more fuzzy sets in the Mamdani method. Determining a fuzzy set is grouping something based on a linguistic variable (linguistic variable) expressed by a membership function in the universe U.
c) Define the membership function, and this process calculates the membership degree function (μ); the data to be calculated membership function is based on the attributes that exist in each fuzzy variable. The discussion of each stage of analyzing fuzzy logic with the Mamdani method is as follows:

3.5. FUZZY VARIABLE

The fuzzy variables used in this study are:

a) The amount of water is the amount of water provided for testing, and the turbidity of the water is measured.
b) The scattered light is light that spreads when it enters the water
c) Turbidity is the effect caused by a collection of particles that gather to cover the level of light entering the water.

3.6. DETERMINING THE FUZZY SET

In this study, the variables are divided into two parts, namely input variables, and output variables.

Table 1 . Input & Output Variables

Function	Variable	Fuzzy Set	Domain	Universe of Conversation
Input	Lots of water	Lots	[26-41]	[0-41]
		Medium	[13-28]	
		Little	[0-15]	
	Light Transmittance and Scatter	High	[>2048]	[0-4906]
		Medium	[1430-2660]	
		Low	[<2048]	
Output	Turbidity	cloudy	[>10]	[0-20]
		Medium	[7-13]	
		Clear	[<10]	

The input variables are a lot of water, transmittance & light scattering. In contrast, the output variable is turbidity. The universe of conversation for input and output variables can be seen in table 1.

3.7. MEMBERSHIP FUNCTION

a. Input Set

The set of inputs in the membership function is:

1. Variable Lots of Water

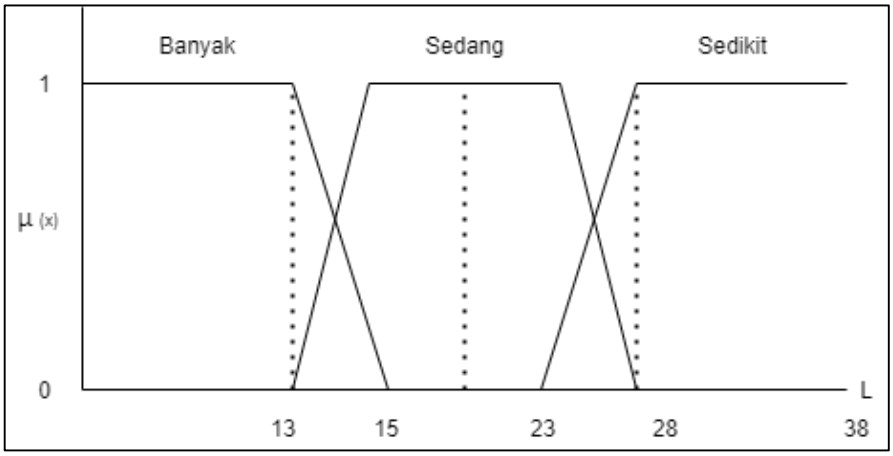

Figure 3. Graph of Variable Amount of Water

The variable amount of water (denoted as x) is divided into three fuzzy sets, i.e., LOTS, MEDIUM, and LITTLE. The following membership function represents the fuzzy set:

$$\mu_{\text{Banyak}} = \begin{cases} 1, x \leq 15 \\ \frac{15-x}{2}, 13 < x \leq 15 \\ 0, x \geq 15 \end{cases}$$

$$\mu_{\text{Sedang}} = \begin{cases} \frac{x-13}{2}, 13 < x < 15 \\ 1, 15 \leq x \leq 23 \\ \frac{28-x}{2}, 23 \leq x \leq 28 \end{cases}$$

$$\mu_{\text{Sedikit}} = \begin{cases} \frac{x-28}{2}, 28 \leq x \leq 38 \\ 1, x \geq 38 \end{cases}$$

2. Variable Transmittance & Light Scatter

Variable Transmittance & Light Scatter can be seen in Figure 4.

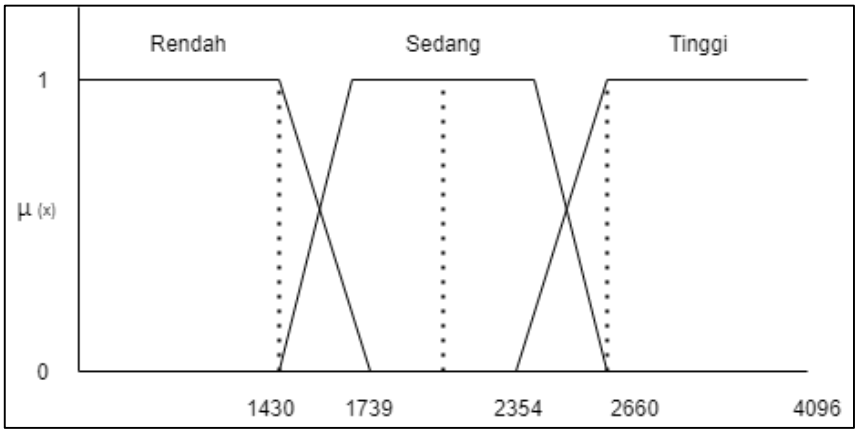

Figure 4. Graph of Variable Transmittance & Light Scatter

The Transmittance & Light Scattering variable (denoted as x) will be divided into three fuzzy sets, i.e., HIGH, MEDIUM, and LOW. The following membership function represents the fuzzy set:

$$\mu_{\text{Tinggi}} = \begin{cases} 1, x \leq 1739 \\ \dfrac{1739 - x}{2}, 1430 < x \leq 1739 \\ 0, x \geq 1739 \end{cases}$$

$$\mu_{\text{Sedang}} = \begin{cases} \dfrac{x-1430}{2}, 1430 < x \leq 1739 \\ 1, 1739 \leq x \leq 2354 \\ \dfrac{2660-x}{2}, 2354 \leq x \leq 2660 \end{cases}$$

$$\mu_{\text{Rendah}} = \begin{cases} \dfrac{x-2660}{2}, 2660 \leq x \leq 4096 \\ 1, x \geq 4096 \end{cases}$$

b. Output Set

The output set in the membership function includes:

1. Turbidity Variable

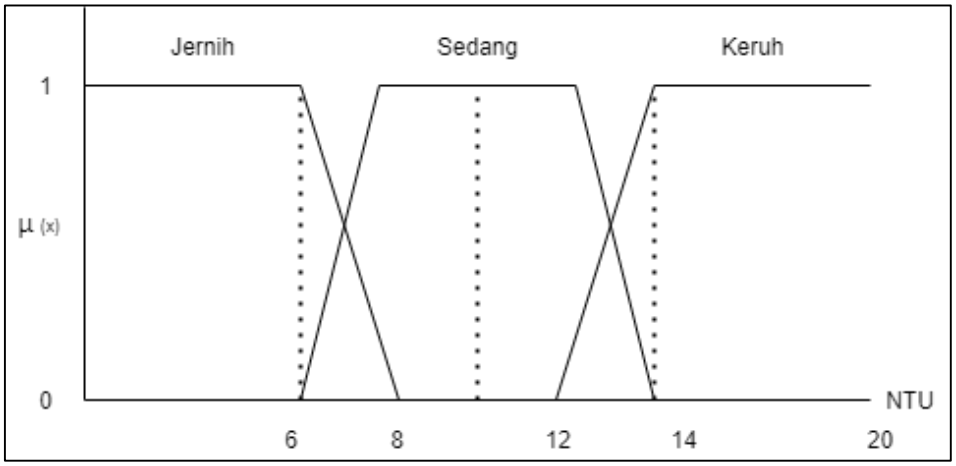

Figure 5. Graph of Turbidity Variable

The variable amount of water (denoted as x) will be divided into three fuzzy sets: CLEAR, MEDIUM, and TURNED. The following membership function represents the fuzzy set:

$$\mu_{Jernih} = \begin{cases} 1, x \leq 8 \\ \frac{0-x}{2}, 6 < x \leq 8 \\ 0, x \geq 8 \end{cases}$$

$$\mu_{Sedang} = \begin{cases} \frac{x-6}{2}, 6 < x < 8 \\ 1, 8 \leq x \leq 12 \\ \frac{14-x}{2}, 12 \leq x \leq 14 \end{cases}$$

$$\mu_{Keruh} = \begin{cases} \frac{x-14}{2}, 14 \leq x \leq 20 \\ 1, x \geq 20 \end{cases}$$

4. RESULT AND DISCUSSION

4.1. Data Processing Using the Fuzzy Mamdani Method

The data obtained in this study is processed using the Mamdani fuzzy method. There are four stages of data processing using Mamdani to obtain the output, i.e., determination of fuzzy set, fuzzification, fuzzy rule formation, and defuzzification. Moreover, the Following are the stages:

4.2. Determining the Fuzzy Set

In this study, the variables are divided into two parts, namely input variables, and output variables. The input variables consist of a lot of water, transmittance & light Scattering. In comparison, the output variable consists of turbidity. The universe of conversation for input and output variables can be seen in table 2.

Table 2. Input & Output Variables

Function	Variable	Fuzzy Set	Domain	Universe of Conversation
Input	Lots of water	Lots	[26-41]	[0-41]
		Medium	[13-28]	
		A little	[0-15]	
	Light Transmittance and Scatter	High	[>2048]	[0-4906]
		Medium	[1430-2660]	
		Low	[<2048]	
Output	Turbidity	cloudy	[>10]	[0-20]
		Medium	[7-13]	
		Clear	[<10]	

4.3 Determining the Fuzzy Set

Determining Fuzzification

a. Input Set

The set of inputs in the membership function is as follows

1. Variable Lots of Water

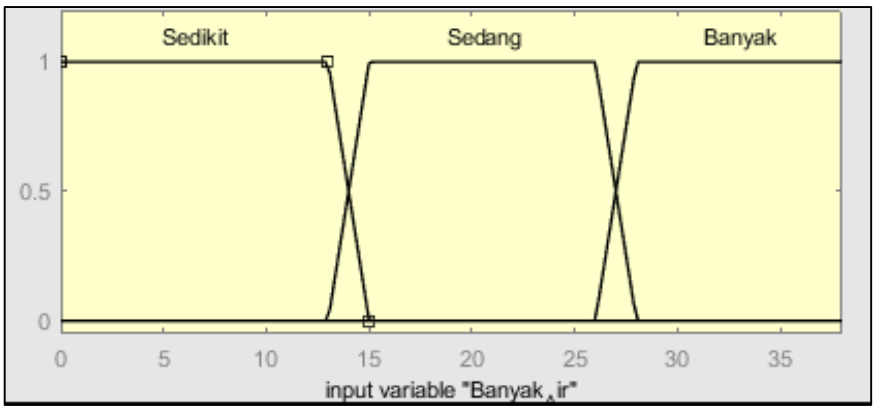

Figure 6. Graph of the Set of Many Water Variables

The variable amount of water (denoted as x) will be divided into three fuzzy sets: LOTS, MEDIUM, and LITTLE. The following membership function represents the fuzzy set:

$$\mu \text{ Banyak} = \begin{cases} 1, x \leq 15 \\ \dfrac{15 - x}{2}, 13 < x \leq 15 \\ 0, x \geq 15 \end{cases}$$

$$\mu\text{Sedang} = \begin{cases} \dfrac{x-13}{2}, 13 < \text{x} < 15 \\ 1, 15 \leq x \leq 23 \\ \dfrac{28-x}{2}, 23 \leq x \leq 28 \end{cases}$$

$$\mu\text{Sedikit} = \begin{cases} \dfrac{x-28}{2}, 28 \leq \text{x} \leq 38 \\ 1, x \geq 38 \end{cases}$$

2. Variable Transmittance & Light Scatter

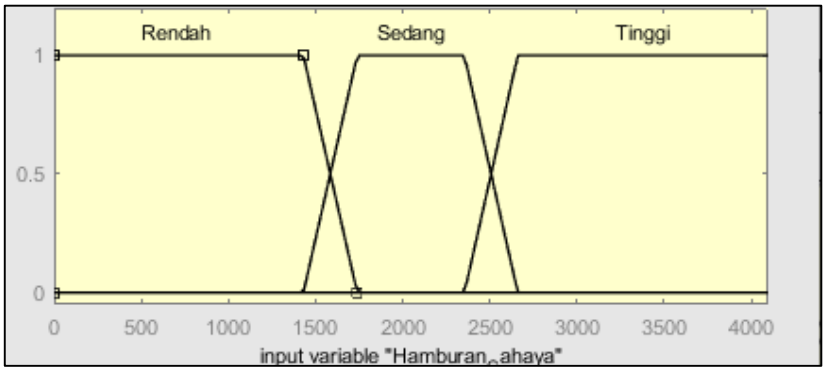

Figure 7. Graph of the Set of Transmittance & Light Scatter Variables

The Transmittance & Light Scattering variable (denoted as x) will be divided into three fuzzy sets: HIGH, MEDIUM, and LOW. The following membership function represents the fuzzy set:

$$\mu \text{ Tinggi} = \begin{cases} 1, x \leq 1739 \\ \dfrac{1739 - x}{2}, 1430 < x \leq 1739 \\ 0, x \geq 1739 \end{cases}$$

$$\mu\text{Sedang} = \begin{cases} \frac{x-1430}{2}, 1430 < \text{x} \leq 1739 \\ 1, 1739 \leq x \leq 2354 \\ \frac{2660-x}{2}, 2354 \leq x \leq 2660 \end{cases}$$

$$\mu\text{Rendah} = \begin{cases} \frac{x-2660}{2}, 2660 \leq \text{x} \leq 4096 \\ 1, x \geq 4096 \end{cases}$$

b. Output Set

The output set in the membership function includes:

1. Turbidity Variable

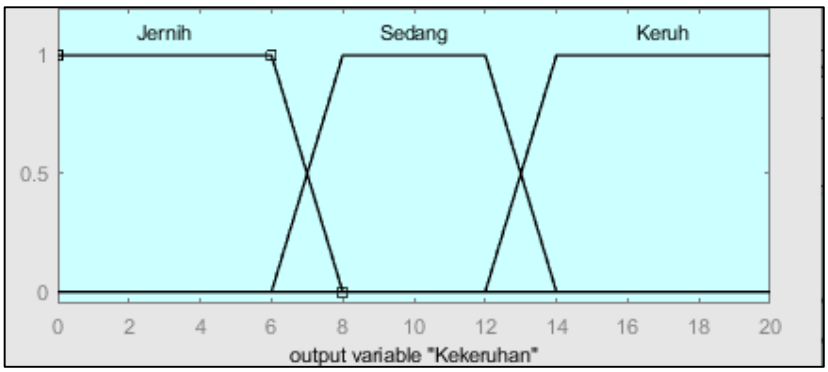

Figure 8. Graph of the Set of Turbidity Variables

The variable amount of water (denoted as x) will be divided into three fuzzy sets: CLEAR, MEDIUM, and TURNED. The following membership function represents the fuzzy set:

$$\mu \text{ Jernih} = \begin{cases} 1, x \leq 8 \\ \dfrac{0-x}{2}, 6 < x \leq 8 \\ 0, x \geq 8 \end{cases}$$

$$\mu\text{Sedang} = \begin{cases} \dfrac{x-6}{2}, 6 < \text{x} < 8 \\ 1, 8 \leq x \leq 12 \\ \dfrac{14-x}{2}, 12 \leq x \leq 14 \end{cases}$$

$$\mu\text{Keruh} = \begin{cases} \dfrac{x-14}{2}, 14 \leq \text{x} \leq 20 \\ 1, x \geq 20 \end{cases}$$

4.4. Fuzzy Rules

The following are several fuzzy rules used in data analysis, as shown in table 3.

Table 3. Description of Rules

NO	Description of Rules		
	Lots of water	**Light Scattering & Transmittance**	**Turbidity**
1	Lots	High	Cloudy
2	Lots	Medium	Medium
3	Lots	Low	Clear
4	Medium	High	cloudy
5	Medium	Medium	Medium
6	Medium	Low	Clear
7	Little	High	Cloudy
8	Little	Medium	Medium
9	Little	Low	Clear

Based on table 2, the fuzzification process for each set of inputs which includes the amount of water variable, light Scattering, and transmittance for each water, is as follows:

a. Sample 1

Sample 1 on a lot of water variable with a value of 18 liters, then the degree of membership can be stated as follows:

$$\mu \text{ Banyak } [18] = \begin{cases} 0, & x \geq 15 \\ 0,18 & \geq 15 \end{cases}$$

$$\mu \text{ Sedang } [18] = \begin{cases} 1, & 15 \leq x \leq 23 \\ 1,15 & \leq 18 \leq 23 \end{cases}$$

$$\mu \text{ Sedikit } [18] = \begin{cases} 0, & x \leq 38 \\ 0,18 & \leq 38 \end{cases}$$

Sample 1 on the variable transmittance and light scattering with a value of 1600, then the degree of membership can be stated as follows:

$$\mu \text{Tinggi } [1600] = \frac{1739 - y}{2} = 1430 < x \leq 1739$$

$$\frac{1739 - 1600}{2} = 1430 < 1600 \leq 1739$$

$$139 = 1430 < 1600 \leq 1739$$

$$\mu\text{Sedang}[1600] = \frac{x - 1430}{2} = 1430 < x \leq 1739$$

$$\frac{1600 - 1430}{2} = 1430 < 1600 \leq 1739$$

$$230 = 1430 < 1600 \leq 173$$

$$\mu\text{Rendah}[1600] = 0 = x \leq 4096$$

$$0 = 1600 \leq 4096$$

The fuzzification results obtained from calculating the membership function of the variable amount of water and light scattering can be seen in table 4.

Table 4. Fuzzification Results

Variable Lots of Water	μ[-]	Light Scatter Variable	μ[-]
μBANYAK[18]	0	μTINGGI[1600]	1
μSEDANG[18]	1	μSEDANG[1600]	1
μSEDIKIT[18]	0	μRENDAH[1600]	0

Application Function Implication

After forming the fuzzy set, fuzzy rules are formed in the form of implications that map between input-output using the MIN function. The results of this process are shown in table 5.

Table 5. Application Function Implication

MIN Function Application	**MIN Function Application with membership value**	**Results**
minμBANYAK[18], μRENDAH[1600]	min (0, 0)	0
minμSEDANG[18], μRENDAH[1600]	min(1, 0)	0
minμSEDIKIT[18], μRENDAH[1600]	min(0,0)	0

Composition Rules

After obtaining the value from the MIN implication process, the next step is to implement the full composition rule; the results are as shown in table 6.

Table 6. Composition Rules

Maximus Composition	**Result**
max(0, 0, 0)	0

Defuzzification with Mean of Maximum (MoM) Method

After obtaining the results of implementing the Mean of Maximum (MoM) composition method, the Crips solution is obtained by taking the average value of the

domain, which has a maximum membership value of 0, then from these results, the domain value can be searched by utilizing the membership function of the ascending linear representation and descending linear representation.

Affirmation (defuzzy)

The affirmation method that will be used is the centroid method. For that, we first calculate the moment for each region:

$$\int_{12}^{20}\left(\frac{1}{2}z-\frac{14}{2}\right)z=\left(\frac{1}{2}z-\frac{14}{2}\right)z$$

$$=\left(\left(\frac{1}{2}20-\frac{14}{2}\right)20\right)-\left(\left(\frac{1}{2}12-\frac{14}{2}\right)12\right)$$

$$=\left(\left(\frac{20}{2}-\frac{14}{2}\right)20\right)-\left(\left(\frac{12}{2}-\frac{14}{2}\right)12\right)$$

$$=(60)-(12)$$

$$=72$$

Fuzzy Test Using Matlab

Confirming data from water turbidity using the Mamdani fuzzy method can also be done using the Matlab Fuzzy Toolbox version R2017a. This software serves to calculate the value of the water turbidity variable. Confirmation using Matlab R2017a can be seen in Figure 9:

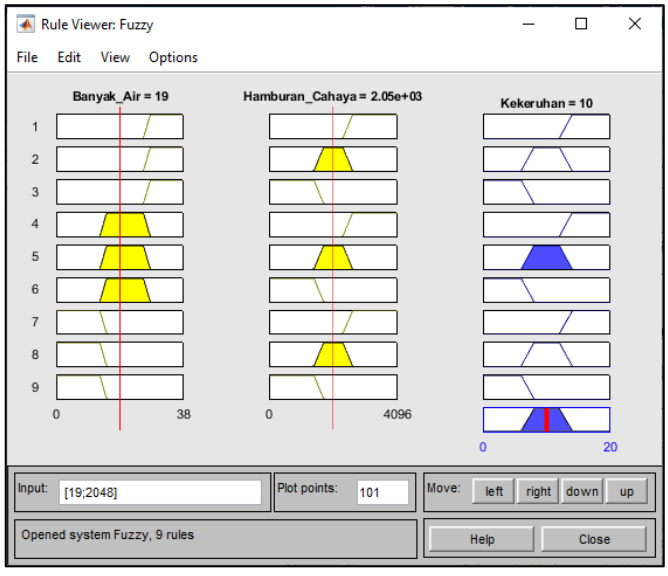

Figure 9. Fuzzy Test with Matlab

Arduino IDE program using the visual C++ language on the circuit. The thing that must be done before running the program is to upload the program to the microcontroller.

At the stage of testing the prototype circuit, Arduino UNO is connected to the LCD, so it is necessary to call the library "#include <LiquidCrystal_I2C.h>"," #include <LCD.h>" which functions to add program functions to display each character on the LCD.

Then "LiquidCrystal_I2C LCD(0x27,2,1,0,4,5,6,7,3, POSITIVE);" is a program listing for setting the location of the LCD foot pins connected to the Arduino Uno pins. The typing of these pins must match the program with the installed device. Furthermore, "LCD.begin(16, 2);" This code is used to adjust the number of columns and rows according to the LCD used because the LCD used is a 16x2 character LCD, the program should be written as "lcd.begin(16, 2);".

The prototype of the measuring instrument only displays data, so the command used is "lcd.clear(); lcd.noCursor();" which means it does not display the cursor on the LCD and can also delete characters on the LCD screen. Then "#include <Wire.h>" is a library that permits communication with LCD I2C or TWI devices.

System Test

To find out that the assembled prototype is operating correctly and per the expectations previously planned, it is necessary to test the prototype. Here are some tests that have been carried out from 5 (five) water aquariums at different times and days. Finally, the Tests on samples are as follows:

System Design Results

The results obtained from the components in this study are that all components have been successfully integrated into the Arduino Uno board for further logic programming so that the system can run as expected in the research objectives. The results of the hardware prototype for measuring water turbidity with the fuzzy method using a microcontroller can be seen in Figure 10.

Arduino IDE program using the visual C++ language on the circuit. The thing that must be done before running the program is to upload the program to the microcontroller. At the stage of testing the prototype circuit, Arduino UNO is connected to the LCD, so it is necessary to call the library "#include <LiquidCrystal_I2C.h>"," #include <LCD.h>" which functions to add program functions to display each character on the LCD.

Furthermore, "LiquidCrystal_I2C lcd(0x27,2,1,0,4,5,6,7,3, POSITIVE);" is a program listing for setting the location of the LCD foot pins connected to the Arduino Uno pins. The typing of these pins must match the program with the installed device. Moreover, "lcd.begin(16, 2);" This code is used to adjust the number of columns and rows according to the LCD used because the LCD used is a 16x2 character LCD, the program should be written as "lcd.begin(16, 2);".

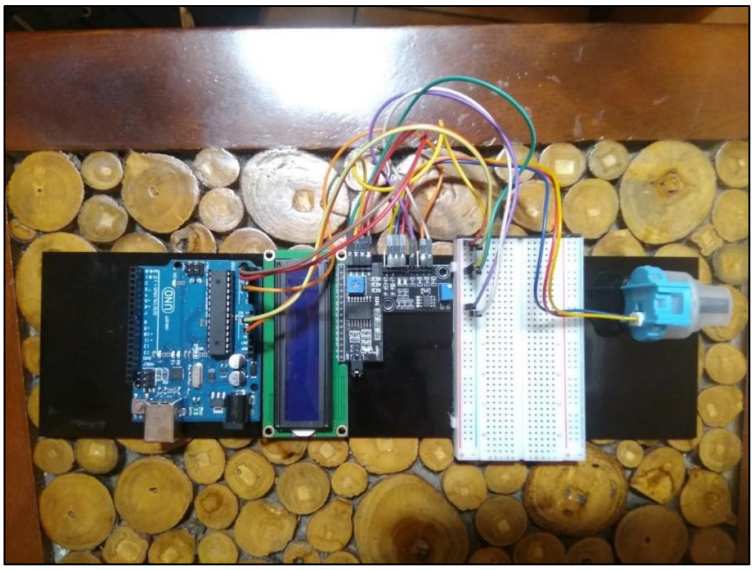

Figure 10. System Design Results

The prototype of the measuring instrument only displays data, so the command used is "lcd.clear(); lcd.noCursor();" which means it does not display the cursor on the LCD and can also delete characters on the LCD screen. Then "#include <Wire.h>" is a library that permits communication with LCD I2C or TWI devices.

Moreover, on the System Test, it is necessary to test the prototype to find out that the assembled prototype is operating correctly and following the expectations that have been previously planned. Here are some tests from 5 (five) water aquariums at different times and days. Moreover, the tests on samples are as follows the table 7.

Table 7. First Test Table

Sample Source	Time	Date	Test
Goldfish Aquarium Water	08.00 WIB	Tuesday, November 3, 2020	1
Goldfish Aquarium Water	08.00 WIB	Wednesday, November 4, 2020	2
Goldfish Aquarium Water	08.00 WIB	Thursday, November 5, 2020	3
Goldfish Aquarium Water	08.00 WIB	Friday, November 6, 2020	4
Goldfish Aquarium Water	08.00 WIB	Saturday, November 7, 2020	5

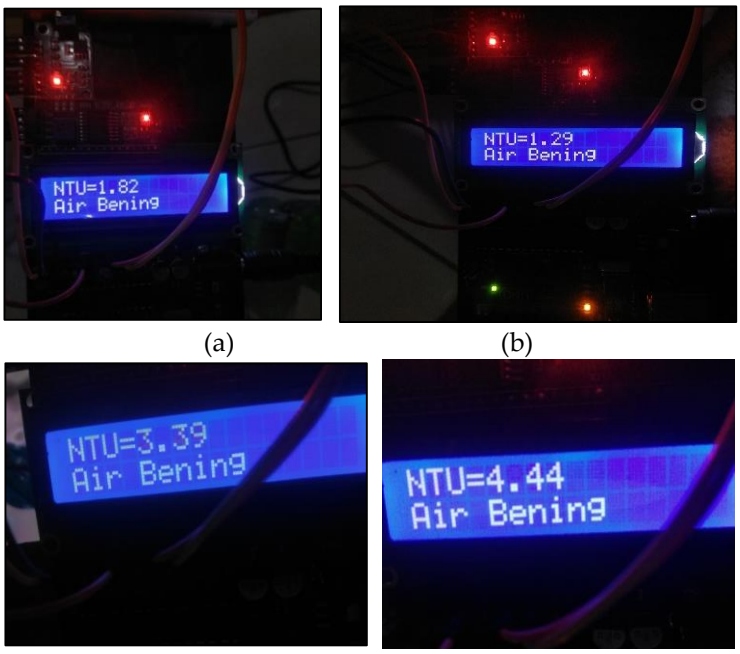

Figure 11. (a) 1st Testing aquarium water, (b) 2nd aquarium water test, (c)3rd aquarium water test, and (d) 4th aquarium water test

Figure 12. 5th aquarium water test

From the measurement of water turbidity that has been carried out on five samples, the following results are obtained: There are as many as 5 (five) measurement samples with different results. These results can be seen in table 8.

Table 8. Table of All Test Results

No	Measurement Time and Date	Water Turbidity Value	Category
1	08.00 WIB ǀ Tuesday, November 3, 2020	1.82 NTU	Clear
2	08.00 WIB ǀ Wednesday, November 4, 2020	1.29 NTU	Clear
3	08.00 WIB ǀ Thursday, November 5, 2020	3.39 NTU	Clear
4	08.00 WIB ǀ Friday, November 6, 2020	4.44 NTU	Clear
5	08.00 WIB ǀ Saturday, November 7, 2020	12.32 NTU	cloudy

Based on the measurement results, it can be seen that from 100% of the samples measured, and there was an increase in turbidity in the aquarium caused by the influence of dirt and food remnants of ornamental fish in the aquarium. For the System Strengths and Weaknesses, The system that has been built certainly has advantages and

disadvantages compared to the previous one. The advantages and disadvantages include:

Moreover, in the System Advantage, The advantages of the system built include:

a) Control and monitoring of ornamental fish aquariums is easier and more efficient

b) Fast response in detecting the level of turbidity of water

And the System Disadvantages, Disadvantages of the system built include:

a) The prototype of the tool that is built is still vulnerable to shocks

b) The cost of some components is relatively expensive.

4. CONCLUSIONS

Based on the results of the design and assembly of a prototype water turbidity measuring device with the fuzzy method using an Arduino Uno microcontroller, several conclusions can be drawn:

a) The assembled water turbidity meter is functioning properly and as planned.

b) This assembled water turbidity meter can be a visualization of the workings of portable water turbidity sensors that are already widely sold in the market.

c) The prototype of the assembled water turbidity meter can speed up the measurement process and can be an alternative for the needs of measuring water turbidity because it has accuracy with a small error rate.

AUTHOR CONTRIBUTIONS

Conceptualization V.M.M.Siregar [V.M.M.S],K.Sinaga [K.S], M.A.Hanafiah [M.A.H]; methodology; [V.M.M.S], [K.S], [M.A.H] ; validation; [V.M.M.S], [K.S], [M.A.H], formal analysis; [V.M.M.S], [K.S], [M.A.H]; investigation; [V.M.M.S], [K.S], [M.A.H], data curation; [V.M.M.S], [K.S], [M.A.H], writing—original draft preparation; [V.M.M.S], [K.S], [M.A.H], ;writing—review and editing; [V.M.M.S], [K.S], [M.A.H]; visualization; [V.M.M.S], [K.S], [M.A.H]; supervision; [V.M.M.S], [K.S], [M.A.H], project administration; [V.M.M.S], [K.S], [M.A.H]; funding acquisition; [V.M.M.S], [K.S], [M.A.H]; have read and agreed to the published version of the manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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