Prediction of Freshwater Fish Disease Severity Based on Fuzzy Logic Approach, Arduino IDE and Proteus ISIS

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Ridwan Siskandar[1*], Wiyoto Wiyoto[2], Sesar Husen Santosa[3], Agung Prayudha Hidayat[3], Billi Rifa Kusumah[4], Muhammad Danang Mukti Darmawan[1]

[1]Computer Engineering Study Program, College of Vocational Studies, IPB University, Bogor, West Java 16151, Indonesia [2]Production Technology and Management of Aquaculture Study Program, College of Vocational Studies, IPB University, Bogor, West Java 16151, Indonesia
[3]Industrial Management Study Program, College of Vocational Studies, IPB University, Bogor, West Java 16151, Indonesia [4]Fishing [4]Technology Study Program, Faculty of Marine and Fisheries Technology, Nahdlatul Ulama University of Cirebon, Cirebon 45111, Indonesia
*Corresponding Author: ridwansiskandar@apps.ipb.ac.id

Abstract This study examines the importance of maintaining the health quality of freshwater fish to increase aquaculture yields. Fish diseases such as Ichthyophthirius, Saprolegniasis, and Columnaris are often a serious threat to freshwater fish farmers. The purpose of this study was to predict the severity of fish disease and diagnosis of freshwater fish disease by calculating the inputs of water clarity, water temperature, oxygen levels, mild disease, moderate disease, and severe disease. The fuzzy logic method (fuzzy membership function, fuzzy rule base, defuzzification) is used to predict the output variable in the form of disease severity and disease diagnosis. The simulation of the fuzzy logic approach through analytical and computational calculations (MATLAB software) produces variable output values (disease severity and disease diagnosis values) that are exactly the same as the results of programming simulations based on Arduino IDE and Proteus ISIS. This shows that the integration of the two simulations has been going well. The results of the simulation measurements are displayed on the LCD display by displaying the variable values

Keywords Arduino IDE, Disease diagnosis, Fuzzy logic, MATLAB, Freshwater fish disease severity

1. Introduction

Research related to the health quality of freshwater fish is currently very interesting to study. Previous researchers have revealed important things related to quality in fish farming [1–14]. Freshwater fish is one of the leading commodities in the fisheries sector which has significant economic value [15–19]. However, fish production is often hampered by the threat of disease which can cause a decrease in the quality of fish culture results. Some common diseases found in freshwater fish are Ichthyophthirius (Ick), Saprolegniasis (Sap), and Columnaris (Col).

Ick is a disease caused by parasitic protozoa of the genus Ichthyophthirius. This disease often occurs in fish that are stressed or have a weakened immune system. If not handled properly, Ick can cause mass mortality in fish populations [20–23]. Sap is a disease caused by a fungus from the genus Saprolegnia characterized by the appearance of white or gray threads on the body of the fish which then develop into a white or green coating. Severe infection can damage the skin and tissue of fish and cause secondary infection by bacteria [1,5,23]. Col, which is commonly known as spotting mouth disease, is caused by bacteria from the genus Flavobacterium. This disease often attacks fish with a weak immune system. Severe infections can damage internal organs and lead to fish death [24–26].

Previous studies reviewed by [11], identified environmental factors that play a role in disease development in freshwater fish. Oxygen levels, water clarity, and water temperature have been shown to affect fish health and promote disease development. Poor water quality, including low oxygen levels, water turbidity, and significant fluctuations in temperature, can weaken fish's immune systems and make them more susceptible to disease infections.

[27], in his research entitled "Training and Assistance in Water Quality and Health Management in Freshwater Fish Cultivation." explains the health of fish has a significant influence on the success of cultivation. Good water quality is a key factor in maintaining fish health, as changes in suboptimal water quality can stress fish and cause disease. In addition, a balanced and quality feed intake is also very important to keep the fish's immune system strong and able to fight infection.

Furthermore, [28] reviewed the research entitled "Detection of Bacterial and Parasitic Diseases in Freshwater Fish". This research found that bacterial and parasitic diseases of freshwater fish have a significant impact on quality deterioration in aquaculture. These diseases can have a variety of adverse effects, such as reduction in fish growth, damage to internal organs, and even mass mortality. In addition, disease also has the potential to cause disturbances in the reproductive system of freshwater fish, which has an impact on decreasing the number and quality of eggs produced.

Given the negative impacts caused by the above diseases, maintaining the health quality of freshwater fish is very important. One approach that can be used to overcome this problem is to apply a fuzzy logic approach. Fuzzy logic is an effective tool for dealing with uncertainty in data-driven decision making. This research goal is to make predictions the severity of fish disease and diagnosis of freshwater fish disease through input calculations of water clarity, water temperature, oxygen levels, mild disease, moderate disease and severe disease. By performing analytical and computational calculations using the fuzzy mamdani method, and also performing tool simulations using the Arduino IDE and Proteus ISIS.

2. Materials and Methods

This research was carried out between March 2023 and June 2023 at the Hardware Laboratory of the Computer Engineering Technology Study Program, Vocational School of IPB. The tools and materials used are shown in Table 1.

Table 1. The need for Tools and Materials

No	Materials and Tools	Function	Volume
1	MATLAB software	Used to analyze data, design algorithms, generate models, and develop applications since it is a matrix-based programming language.	1 units
2	Arduino IDE software	Used to create, edit a program code, verify, and upload program code to arduino	1 units
3	ISIS's Proteus Software	Used for the simulation of electronic circuits that are made.	1 units
4	Experts/experts in the field of freshwater fish diseases	As a source of information in determining the membership function of fuzzy logic	2 experts

The development of a prediction model for the severity of freshwater fish disease to improve the quality of aquaculture products is carried out using a fuzzy logic approach. [29–31] have recommended utilizing the Mamdani fuzzy inferences system, which processes data using an inference engine to provide specific outcomes in the process of defuzzing the variables it possesses, to construct a suitable fuzzy model. The following are the steps involved in creating the fuzzy model.

2.1. Membership Function Of Fuzzy

Fuzzy membership sets are used to determine the boundaries of each parameter used in variables that have fuzzy areas. The membership sets used to determine water clarity, water temperature, water oxidation, diagnosis of mild disease, diagnosis of moderate disease and diagnosis of severe disease are triangular and trapezoidal types.

2.1.1. Triangular Membership Association

A triangle membership set graph is used to determine the membership degree of the highest value. Membership set for the Triangular Membership Function graph μF (a, b, c): R → [0,1] [32]. The Tringular Membership Function graph is shown in Figure 1 [32].

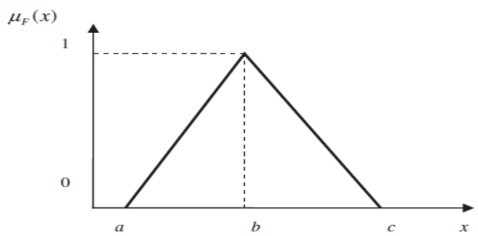


Figure 1. Tringular Membership Function

2.1.2. Trapezoidal Membership Association

Graph Triangular membership sets have more than one highest degree of membership value. The membership set for the Trapezoidal Membership Function graph μF (a, b1,b2, c): R → [0,1]. The trapezoidal membership function graph is shown in Figure 2 [33].

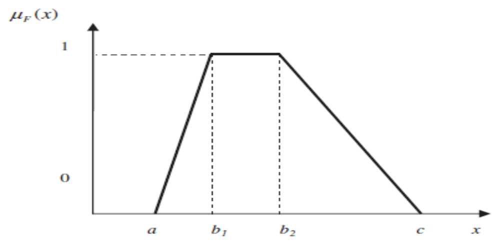


Figure 2. Trapezoidal Membership Function

2.2. Rule Base of Fuzzy

The rules of fuzzy (Fuzzy Rule Base) in the management of input variables use the "IF THAN ELSE" principle. The fuzzy logic rules used are Ri: If X_1 is A_{1i} and X_2 is A_{2i} and ⋯ X_m is A_{mi} Then Y is B_i; i = 1; 2;…n. The principle in determining the fuzzy operator on the input variable is using "and" so that the selected operator value for area and moment is the operator with the "minimum" value.

2.3. Defuzzification

The Center of Area (COA) method is used to determine water clarity, water temperature and water oxidation which is then used as the basis for disease severity. While the value of the severity of the disease is used to determine the diagnosis of mild disease, moderate disease and severe disease which is then used as the basis for the type of disease diagnosis indicated. Fuzzy values obtained from the area and moments obtained from the obtained fuzzy rules. The COA method formula is shown in equation 1.

$$XCOA = \frac{\int_{x=0}^{n} \mu A(x) x \, dx}{\int_{x=0}^{n} \mu A(x) \, dx} \quad (1)$$

3. Results and Discussion

Development of Prediction of Freshwater Fish Disease Severity using a fuzzy logic approach in determining the severity of freshwater fish disease. Flow Chart for Prediction of Freshwater Fish Disease Severity is shown in Figure 3.

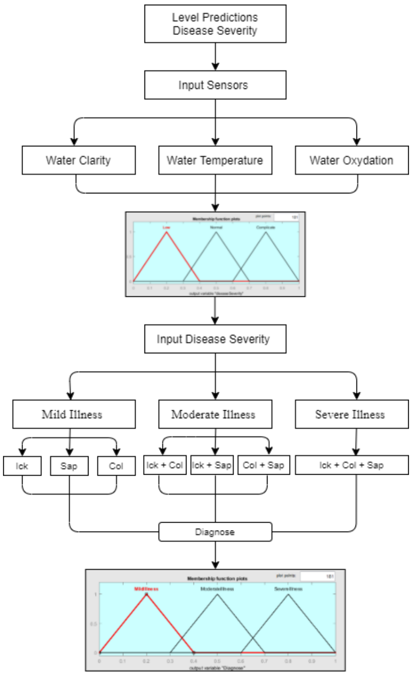
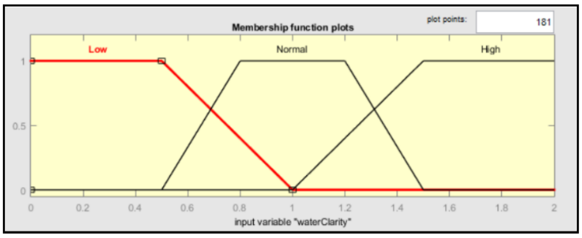


Figure 3. Flow Chart for Prediction of Freshwater Fish Disease Severity

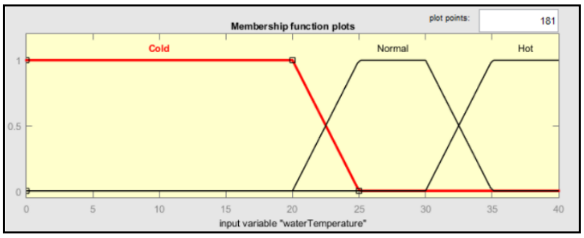
The development of fuzzy logic in predicting the severity of freshwater fish disease has several stages and uses the Matlab application to create a fuzzy set model. The stages of the model simulation and the results of the defuzzification of the severity of the disease and the diagnosis of the type of disease in the MATLAB application are as follows.

3.1. Membership Association of Disease Severity Level

Membership fees are based on the conditions resulting from interviews with experts. The input variables used are the results of turbidity sensor readings, water temperature sensor readings and oxidation results readings in fish ponds. Below is a graph of the membership functions used in Figure 4.



(a)



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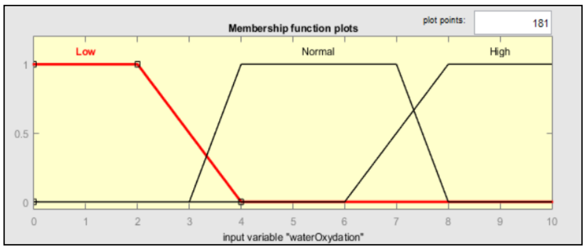


(c)

Figure 4. Membership Function: (a) Water Clarity Membership Function , (b) Water Temperature Membership Function, (c) Water Oxidation Membership Function

The output membership set of this fuzzy model is the level of severity experienced by fish based on the simulated reading values of the turbidity sensor, temperature sensor and water oxidation sensor. The membership set of disease severity uses three parameters, namely low, normal and high. The set of fuzzy membership of disease severity is shown in Figure 5.

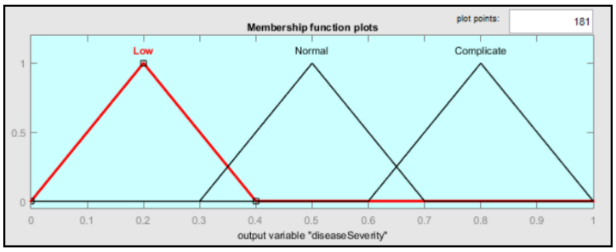
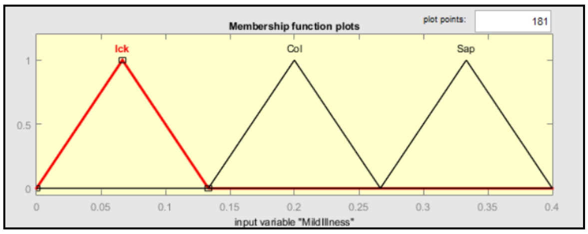


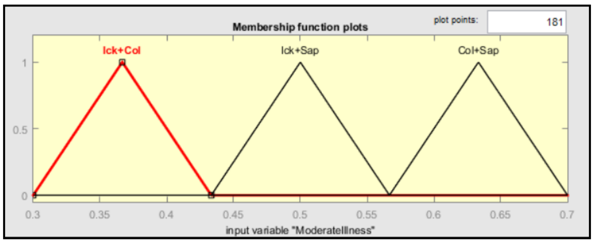
Figure 4. Disease Severity Membership Function

3.2. Membership Association for Disease Diagnosis

The disease diagnosis membership set was built based on the results of interviews with experts. The input variables used are readings indicating mild disease, moderate disease and severe disease. The membership function graph used is shown in Figure 6.



(a)



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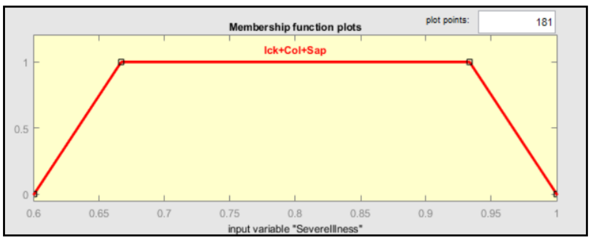


(c)

Figure 6. Membership Function: (a) Mild Illness Membership Function , (b) Moderate Illness Membership Function, (c) Severe Illness Membership Function

The output membership set of this fuzzy model is the diagnosis of fresh water fish disease based on the severity of the disease. Freshwater fish experience mild disease, if the fish only has one disease. Freshwater fish have moderate disease, if fish are infected with two diseases and Freshwater fish have severe disease, if fish are infected with three diseases. Parameters for the definition of mild, moderate and severe disease are more clearly shown in Table 2.

Table 2. Parameters for The Definition of Mild, Moderate and Severe Dosease

Variable	Fuzzy Set	Domain
Mild Illness (Infected by One Disease)	Ick Col Sap	[0-0.13] [0.13-0.26] [0.26-0.4]
Moderate Illness (Infected with two diseases)	Ick + Col Ick + Sap Col + Sap	[0.3-0.43] [0.43-0.56] [0.56-0.7]
Severe Illness (Three Illnesses)	Ick + Col + Sap	[0.6-1]

To determine the domain from the fuzzy logic results, a conversion is needed related to the output value of the existing disease types. For output with mild results, it will have a domain with conditions 0 to 0.13 if infected with Ichthyophthirius disease, for domains 0.14 to 0.26 if infected with Columnaris disease and for domains 0.27 to 0.4 if infected with Saprolegniasis disease. Output with moderate results will have domains with conditions 0.3 to 0.43 if infected with Ichthyophthirius and Columnaris, for domains 0.44 to 0.56 if infected with Ichthyophthirius and Saprolegniasis for domains 0.57 up to. 0.7 if infected with Saprolegniasis and Columnaris. Outputs with severe results will have domains with conditions 0.6 through 0.1 if infected with Ichthyophthirius, Columnaris and Saprolegniasis. This domain is obtained from the results of interviews with experts.

The membership set of disease severity uses three parameters, namely mild disease, moderate disease and severe disease. More specifically, the fuzzy membership set is shown in Figure 7.

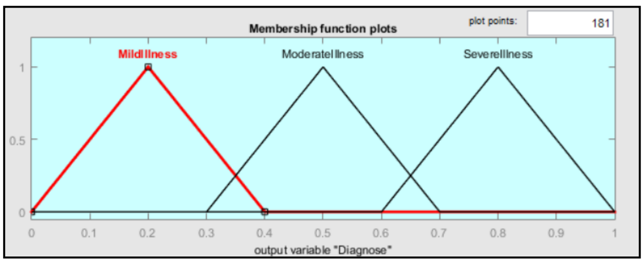
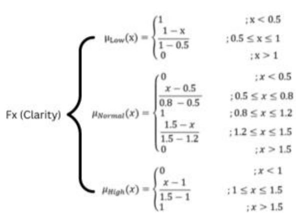


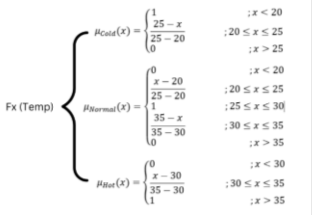
Figure 7. Membership Function

The model verification process is carried out with two readings, first to find out the value obtained by the sensor simulation readings and then the results are recalculated to get the results of a disease diagnosis. The first step is to enter the turbidity sensor simulation reading value of 1.2 NTU so that the degree of membership value for water turbidity is µTurbidity (a,b,c) = 1; the reading of the temperature sensor is 26ºC, so the value of the degree of membership of the water temperature is µTemperature (a,b,c) = 1; and the reading of the oxidation sensor is 5.5 PPM so that the value of the degree of membership of the oxidation of water is µOxy (a,b,c) = 1.

The second step is by entering the input into the entire membership set in the amount of the output obtained, assuming 0.5. The degree of membership for the severity of the disease and the diagnosis of the type of disease are shown in Figure 8 and Figure 9.



(a)



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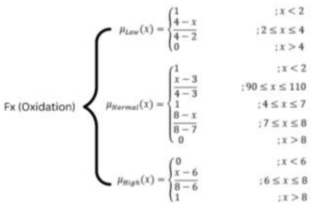

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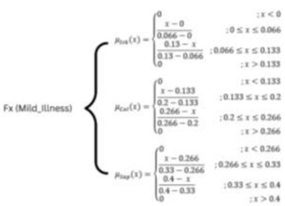
Figure 8. (a) Degree of Membership of Water Turbidity, (b) Degree of Membership of Water Temperature, (c) Degree of Membership of Water Oxidation



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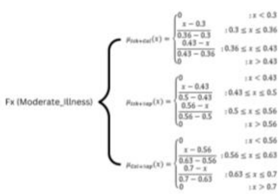

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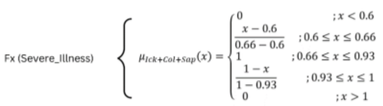

(c)

Figure 9. (a) Degree of Membership of Mild Illness, (b) Degree of Membership of Moderate Illness, (c) Degree of Membership of Severe Illness

3.3. Rule Base of Fuzzy Disease Severity and Dissease DIagnose

The fuzzy rule base that can occur for the input variables is determined based on the set of degrees of membership of the input and output variables. Based on the values of the 'and' and 'min' operators, there are 8 possibilities for disease severity and 16 possibilities for disease diagnosis. A fuzzy rule-based simulation using the Matlab application rule editor is shown below Figure 10 and Figure 11.

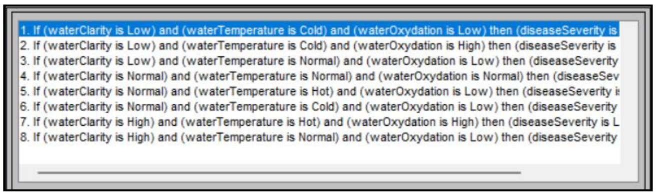

Figure 10. Fuzzy Rule Base For Disease Severity in Matlab Aplication

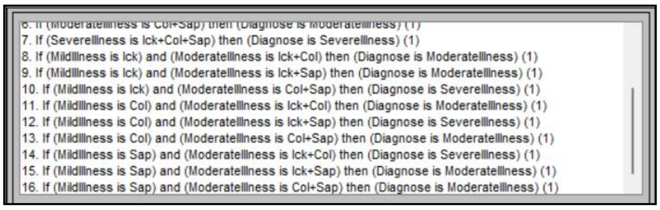

Figure 11. Fuzzy Rule Base For Disease Diagnose in Matlab Aplication

3.4. Defuzzification of Severity of Disease

Based on the results of the fuzzy rule base, the value of the operator used can be determined by the degree of fuzzy membership to disease severity. The obtained operator values are as follows.

α = Min ($\mu\_{Keruh\ [1.2]} \cap \mu\_{Suhu[26]} \cap \mu\_{Oxy\ [5.5]}$)
= Min (1; 1; 1)
α = 1

Furthermore, disease severity defuzzification is achieved by computing the center of area (COA) method by comparing the resulting moments with the area of the disease severity output variable. The total moment obtained for the simulated disease severity is 0.1. Disease severity moments based on fuzzy membership set results are shown in Equation 2. .

$$\int_{0.3}^{0.7} 0,5\ x\ dx \qquad (2)$$

The result of determining the total area (LD) of the disease severity fuzzy membership set is 0.2. Validation of the area values produced by the disease severity member set is :

$$LD = \frac{(0.7 - 0.3) \times 1}{2} = 0,2$$

Based on the Center of Area (COA) method, which compares moments and areas, the disease severity is 0.5, indicating moderate disease. A defuzzification check of disease severity using Matlab software gave the same result, namely 0.5. . Defuzzification using the Matlab software is shown in Figure 12. The defuzzification calculation of the fish disease diagnosis value was carried out using the same method as the defuzzification calculation of the severity of fish disease.

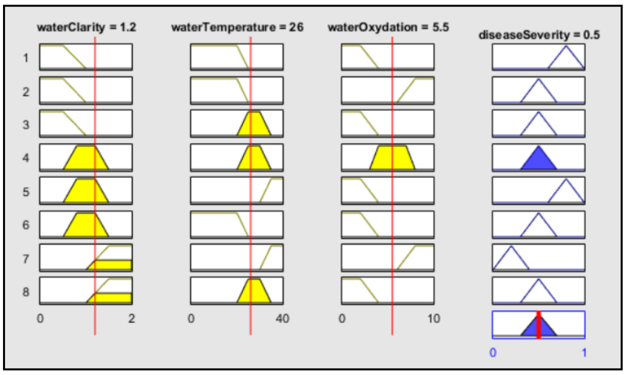

Figure 12. Defuzzification of Disease Severity using Matlab Software

3.5. Application of The Severity of Fuzzy Disease in The Simulation Arduino IDE & Proteus ISIS

Detection results can provide information on how infected freshwater fish are with respect to disease severity and disease diagnosis, to answer whether the disease severity is mild, moderate, or severe. This diagnosis consists of an integrated device sensor simulation, namely the water temperature sensor (Figure 13 number 3), the turbidity sensor (Figure 13 number 5) and the dissolve oxygen sensor (Figure 13 number 7). The results of the simulation measurements are displayed on the LCD display (Figure 13 number 6) by displaying the disease conditions of freshwater fish. This detection is based on Arduino IDE simulation with fuzzy program code in it. Calculations that have been done before, both analytically and computationally, are entered into the Arduino simulation in the Proteus ISIS software. An overview of the schematic simulation of electronic circuits from the detection of freshwater fish disease predictions is shown in Figure 13.

In this study there were two input variables, namely: the first input was divided into three parts, namely water clarity, water temperature and oxygen levels; and the second input is divided into three parts, namely mild illness, moderate illness and severe illness. From this, there are also two output variables, namely: disease level (output 1) and disease diagnosis (output 2). More specifically, membership values based on numerical variables in the fuzzy set of membership functions for input and output variables are shown in Table 3.

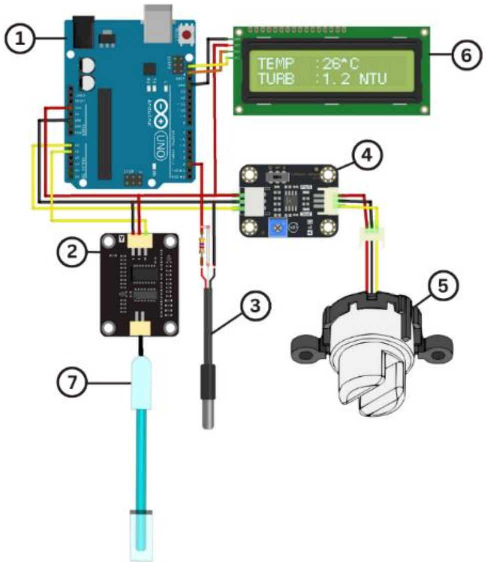

Figure 13. Schematic Simulation of Electronic Circuits from the Prediction of Freshwater Fish Disease Predictions

Table 3. Membership values based on numerical variables in the fuzzy set of membership functions for input and output variables

Input/Output	Variable	Fuzzy Set	Domain
Input Severity Level of Water	Clarity Disease	Low Normal High	[0-1] [0.5-1.5] [1-2]
	Water Temperature	Cold Normal Hot	[0-25] [20-35] [30-40]
	Oxygen Levels	Low Normal High	[0-4] [3-8] [6-10]
Disease Diagnostic Input	Mild Illness (Infected by One Disease)	Ick Col Sap	[0-0.13] [0.13-0.26] [0.26-0.4]
	Moderate Illness (Infected with two diseases)	Ick + Col Ick + Sap Col + Sap	[0.3-0.43] [0.43-0.56] [0.56-0.7]
	Severe Illness (Three Illnesses)	Ick + Col + Sap	[0.6-1]
	Disease Severity	Light Currently Critical	[0-0.4] [0.3-0.7] [0.6-1]

Output	Disease Diagnostic	Mild Illness (Infected by One Disease) Moderate Illness (Infected with two diseases) Severe Illness (Three Illnesses)	[0-0.4] [0.3-0.7] [0.6-1]

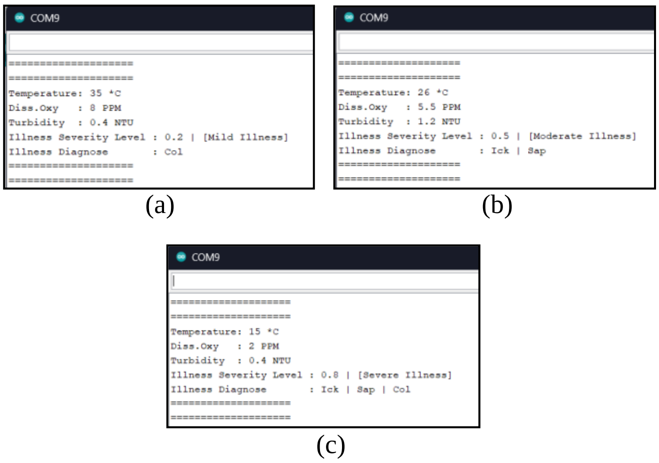

Figure 14. Simulation results of disease severity and diagnosis of disease types using the Arduino IDE simulation in the Proteus ISIS software : (a) Mild Illness; (b) Moderate Illness; (c) Severe Illness

Figure 14 describes the simulation results from Arduino in the Proteus ISIS software. Domain values that are read in the simulation show the conditions of the variables and fuzzy sets that are read. These results are consistent with the results of analytical and computational calculations using the MATLAB software simulation (Figure 12). This is reinforced by the domain values that are consistent with Table 3 regarding the explanation of membership values based on numeric variables in the fuzzy set of the input and output variable membership functions used in the computational simulation of the MATLAB software. Thus, the fuzzy logic approach method using Arduino IDE and proteus ISIS was successfully carried out to predict the severity of fish disease.

4. Conclusion

It has succeeded in developing a fuzzy logic approach model in predicting the severity of freshwater fish disease with the output variable results in the form of disease severity and disease diagnosis. The final output variable results are obtained by calculating the input variables for water clarity, water temperature, oxygen levels, mild illness, moderate illness and severe illness. The fuzzy logic simulation (through the MATLAB application) produces the same value in the Arduino IDE and Proteus ISIS simulation results. This shows that the integration of the model simulation with the electronic device simulation has been going well. The results of the simulation measurements are displayed on the LCD display by displaying the values of the input variables used and the expected output values (severity and diagnosis of the type of freshwater fish disease.

Acknowledgements

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