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Automatic Feeding System for Fish Using Fuzzy Logic Method

Cindy Arditha Claudia Manurung[1*]
[1*]Computer Engineering Technology, College of Vocational School, IPB University
cindyyclaudia@apps.ipb.ac.id

Mohammad Hafiz Fachrezi Lubis[2], **RahiimTahajjadanZhaahir Haq**[3], **SevrilAnugrahKlanaSurbakti**[4], **Zakaria Hidayatullah**[5], **Inna Novianty**[6], **Nanda Octavia**[7], **Ivan De Nerol**[8]
[2345678]Computer Engineering Technology study program, College of Vocational Studies
[2]200346hafiz@apps.ipb.ac.id, [3]rahimtahajjadan@apps.ipb.ac.id, [4]sevrilanugrah@apps.ipb.ac.id, [5]zallahzakaria@apps.ipb.ac.id5, [6]innanovianty@apps.ipb.ac.id, [7]naocaviananda@apps.ipb.ac.id, [8]ivandenerolivan@apps.ipb.ac.id

Abstract

This investigate presents an inventive approach to upgrade angle cultivating hones through the usage of an Programmed Bolstering Framework utilizing Fluffy Rationale. The proposed framework points to optimize the bolstering handle by considering components such as water temperature, water quality, and the time of the past nourishing. Fluffy rationale calculations are utilized to create brilliantly choices with respect to the amount of nourish, sort of bolster, ideal nourishing time, and the in general wellbeing status of the angle. The system's flexibility to changing natural conditions makes it a profitable device for economical aquaculture hones.
Keywords: Aquaculture, Fish Farming, Fuzzy Logic, Feed Optimization, Intelligent Decision Making.

INTRODUCTION

Within the fisheries segment, innovative headways are advancing quickly, presenting different frameworks such as checking, computerization, and the Web of Things (IoT) to encourage the administration of aquaculture. Due to tall advertise request, the utilization of angle, especially tilapia, has gotten to be a well known choice.

In tilapia cultivating, bolster contributes roughly 60% to the victory of generation. Nourishing is ordinarily carried out 2-3 times a day. Tilapia, particularly, is known to be a cannibalistic angle. Unpredictable and postponed nourishing can result in a diminish in angle weight, influence their estimate, and indeed posture potential threats.

The bolstering of tilapia requires the utilize of an robotized framework that can be controlled based on timing and natural conditions. Being cold-blooded creatures, angle have body temperatures that depend on their environment. In this manner, an mechanized nourishing framework competent of altering bolster conveyance based on water temperature and natural conditions gets to be significant.

The perfect water temperature for tilapia development is between 25-32°C, taking under consideration the water profundity within the lake. In spite of the fact that there are numerous robotized nourishing frameworks accessible within the showcase, most of them don't consider natural conditions and can as it were plan nourish conveyance based on time.

Subsequently, in this think about, we utilize Kanno fluffy rationale based on the Web of Things (IoT) to propose an mechanized bolstering framework for tilapia based on water temperature. The framework is prepared with a portable application permitting real-time observing of water temperature and water level, in conjunction with thrust notices when the bolster within the holder is about drained. This probe is anticipated to upgrade the effectiveness and victory rate of tilapia cultivating whereas optimizing thought for the encompassing natural conditions (Somantri, Gina, Siti, and Kamdan, 2023).

METHODS

A.Time and Location

This research was conducted following the Academic Calendar of the IPB University Vocational School, which lasted for approximately 4 months, from January 23, 2024, to June 6, 2024.

B.Equipment and Materials Details

Measures the pH in the tank.

Equipment	Purpose
ESP 32	Control device to operate the system as a whole
Servo MG995	As a feeder door opener.
DC Motor	Fan propeller drive.
Motor Driver	DC motor speed regulator
Servo Motor	To dispense feed.
12V Adapter	As a source of electrical voltage or power used by the equipment.
Ultrasonic Sensor	To check the availability of feed, whether it is still available, half gone, or empty.
LCD I2C	Displays words that function to indicate if the device is in a certain mode.
Temperature Sensor DS18B20	Measures the temperature inside the tank.
pH Sensor 4502C	Measures the pH in the tank.

C.Data Collection Techniques

There are several data collection techniques used in this research, namely :

a)Literature Review

Literature review involves searching for reading sources to be used as benchmarks or references for the creation of the device.

b)Observation

Observation method is a systematic observation process of human activities and physical settings where the activities take place continuously from a natural activity locus to produce facts. Therefore, observation is an integral part of the ethnographic field research scope.

D.Work Procedure

a)Design

The design stage is an advanced stage of the analysis stage. Design starts with the creation of block diagrams and flowcharts with the help of the Draw.io website, circuit scheme design with the help of Fritzing software, device design with the help of fusion software, and system interface design on the web server. a.Hardware Design

Hardware design is the process of designing and developing physical components or hardware for IoT-based systems. Hardware design involves the selection and integration of electronic components, material selection, circuit design, assembly, and testing of the hardware.

b.Software Design

Software design is the process of planning, designing, and developing the structure and functions of software. It involves selecting the appropriate development method, designing system architecture, designing user interfaces, and specifying the components to be created.

E.Implementation

Implementation is the stage after designing the devices that have been made previously. The data results obtained from monitoring the pH and temperature of the catfish pond based on IoT with NodeMCU are then validated.

a)Hardware Implementation

Hardware implementation is the physical result of the device that the author has made. Where the author will show what parts of the aFEESH device and how it works.

b)Software Implementation

Software implementation is the result of monitoring that has been integrated with the website. The results of this monitoring themselves contain the results of measuring the temperature and pH sensors of the water in the fish pond at the IPB University Vocational School.

F.Testing

The testing stage is the final stage of the work procedure, aimed to ensure that the system's operation is as it should be. Testing is done as a verification process that the device meets the requirements.

G.Data Analysis

The data analysis that the author will use is multiple linear regression. Multiple linear regression analysis is conducted to determine the direction and extent of the influence of independent variables on the dependent variable. The dependent variable is the fish feed expenditure, and there are two independent variables, namely temperature value and pH value.

RESULTS AND DISCUSSION

Automatic fish feeding systems employing fuzzy logic control are emerging as a game-changer in aquaculture. Research has yielded promising results, demonstrating significant benefits for both fish health and overall management practices.

Studies comparing fuzzy logic feeders to traditional fixed-schedule feeders have shown positive impacts on fish growth and health. These systems can adjust feeding amounts based on real-time data collected from sensors monitoring water temperature, pH, dissolved oxygen, and even fish activity through image recognition. This data-driven approach allows the system to mimic natural feeding patterns, leading to improved fish growth rates and lower mortality.

Membership Function in Determining Quantity

1.Water Temperature

The image below shows the membership function of the input variable Water Temperature. The Water Temperature variable is created with Trapezoidal and Triangular types ranging from 0°C to 30°C. The linguistic variables used for the Water Temperature input are "Low," "Medium," and "High." The parameter values for "Low" Water Temperature range from 0°C to 25°C, with peak points at 10°C to 20°C. The parameter values for "Medium" Water Temperature range from 24°C to 28°C, with peak points at 25°C to 27°C. And, the parameter values for "High" Water Temperature range from 27°C to 30°C, with peak points at 28°C to 29°C.

Range = $0°C - 30°C$
Low = $0°C - 25°C$
Medium = $24°C - 28°C$
High = $27°C - 30°C$

Case studies with $25°c$
$\mu x = 1$

Then it produces 1

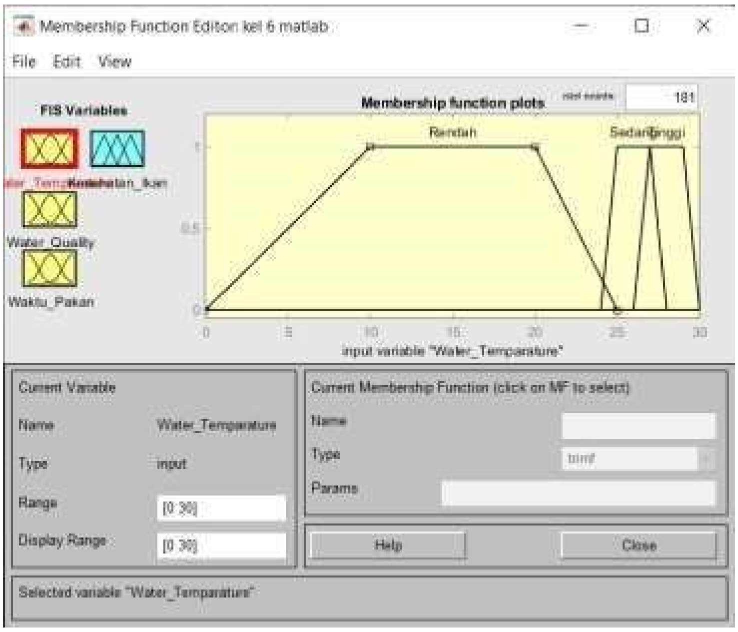

Figure 1. Fuzzy Membership Levels for the Input ‘Water Temperature’

Water Temperature Membership Set

- $x \leq 24 \quad = 0$
- $24 < x < 25 \quad = \frac{x - a}{b - a}$
- $25 \leq x \leq 27 \quad = 1$
- $27 < x < 28 \quad = \frac{d - x}{d - c}$
- $x \geq 28 \quad = 0$

2.Water Quality

The image below shows the membership function of the input variable Water Quality. The Water Quality variable is created with Trapezoidal and Triangular types ranging from 0 pH to 8.5 pH. The linguistic variables used for the Water Quality input are "Poor," "Moderate," and "Good." The parameter values for "Poor" Water Quality range from 0 pH to 6 pH, with peak points at 5 pH to 5.5 pH. The parameter values for "Moderate" Water Quality range from 5.5 pH to 7.5 pH, with peak points at 6 pH to 7 pH. And, the parameter values for "Good" Water Quality range from 7 pH to 8.5 pH, with peak points at 7.5 pH to 8 pH.

Range = 0pH - 8.5 pH
Poor = 0 pH – 6 pH
Fair = 5.5 pH – 7.5 pH
Good = 7 pH – 8.5 pH

Case study with 5.8 pH

$$\mu x = \frac{d\_x}{d\_c} = \frac{6-5,8}{6-5,5} = \frac{0,2}{0,5} = 0,4$$

Then it produces 0.4

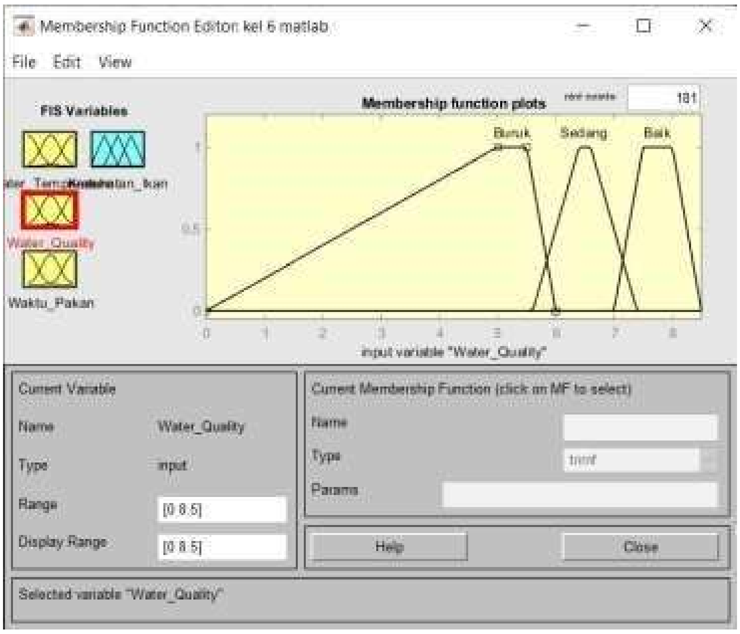

Figure 2. Fuzzy Membership Levels for the Input 'Water Quality'

Water Quality Membership Association

- $x \leq 0 \quad = \quad 0$
- $0 < x < 5 \quad = \frac{x-a}{b-a}$
- $5 \leq x \leq 5,5 \quad = \quad 1$
- $5,5 < x < 6 \quad = \frac{d-x}{d-c}$
- $x \geq 6 \quad = \quad 0$

3.Feeding Time

The image below shows the membership function of the input variable Feeding Time. The Feeding Time variable is created with a Trapezoidal type ranging from 0 to 18. The linguistic variables used for the Feeding Time input are "New" and "Old." The parameter values for "New" Feeding Time range from 6 to 12, with the peak points at 8 to 10. The parameter values for "Old" Feeding Time range from 11 to 18, with the peak points at 13 to 16.

Range = 0 - 18
New = 6 - 12
Long = 11 - 18

Case study with 7 a.m time

$$\mu x = \frac{x-a}{b-a} = \frac{7-6}{8-6} = \frac{1}{2} = 0,5$$

Then it produces 0.5

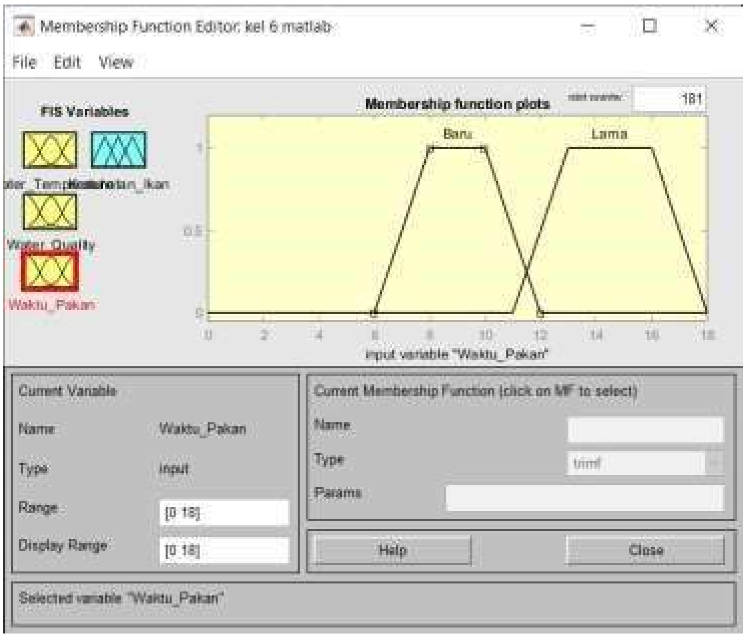

Figure 3 Fuzzy Membership Levels for the Input 'Feeding Time'

Feeding Time Membership Set

- $x \leq 6 = 0$
- $6 < x < 8 = \frac{x - a}{b - a}$
- $8 \leq x \leq 10 = 1$
- $10 < x < 12 = \frac{d - x}{d - c}$
- $x \geq 12 = 0$

Membership Association

Fuzzy Logic has membership. Membership function is a function that includes each member of the assembly with an exact degree of membership or can be called a degree of memberhood in the form of a number at the interval between 0 and 1. This membership is determined through literature reviews and can also be from interviews with experts. From the results of the interview, the range is obtained for each parameter for each variable, and then the calculation is described as follows:

- Trapezoid Formula :*F(x) = {0, x* ≤ $\frac{x-a}{b\_a}$ ≤ ≤ a , a x b 1, b ≤ ≤ $\frac{d-x}{d\_c}$ ≤ ≤ x c , c x d 0, d ≤ x}
- Triangle Formula :*F(x) = {0, x* ≤ $\frac{x-a}{b\_a}$ ≤ ≤ $\frac{c-x}{c\_b}$ ≤ ≤ a , a x b , b x c 0, d ≤ x}

Membership Function

1.Water Temperature membership

- Low Water Temperature (0 - 25 °C) has a membership level µLow (x), a linear function as follows:

µ*Low(x)* {0 *if x* ≤ 0 $\frac{x - 0}{}$

Calculation example: µ*Low*(5) $= \frac{5-0}{10-0} = \frac{5}{10} = 0{,}5$

- Medium Water Temperature (24 - 28 °C) has a membership level μMedium (x), a linear function as follows:

$$\mu Medium(x)\{0\ if\ x \le 24\ \frac{-24}{25-24}\ if\ 24 \le x \le 25\ \frac{1\ if\ 25 \le x \le 27\ \frac{28-x}{28-27}\ if\ 27 \le x \le 28}{if\ x \ge 0 28}\ x$$

Calculation example:

$$\mu Medium(25) = 1$$

- High Water Temperature (27 - 30 °C) has a membership level μHigh (x), a linear function as follows:

$$\mu High(x)\{0\ if\ x \le 27\ \frac{x-27}{28-27}\ if\ 27 \le_x \le 28\ \frac{1\ if\ 28 \le x \le 29\ \frac{30-x}{30-29}\ if\ 29 \le x \le 30}{0\ if\ x \ge 30}$$

Calculation Example:

$$\mu High(29{,}5) = \frac{30-29{,}5}{30-29} = \frac{0{,}5}{1} = 0{,}5$$

Calculation for *f*(water temperature):

- Low Water Temperature of 5 °C in the range of 0 °C to 25 °C have a membership level *μLow(x)* of 0.5
- Medium Water Temperatures of 25 °C in the range of 24 °C to 28 °C have a membership level *μMedium(x)* of 1
- High Water Temperatures of 29,5 °C in the range of 27 °C to 30 °C have a membership level *μHigh(x)* of 0.5

2.Water Quality membership

•Poor Water Quality (0 pH – 6 pH) has a membership level μPoor (x), a linear function as follows:

$$\mu Poor(x)\{0\ if\ x \le 0\ \frac{x-0}{5-0}\ if\ 0 \le_x \le 5\ \frac{1\ if\ 5 \le x \le 5.5\ \frac{6-x}{6-5.5}\ if\ 5.5 \le x \le 6}{0\ if\ x \ge 6}$$

Calculation example:

$$\mu Poor(2{,}5) = \frac{2{,}5-0}{5-0} = \frac{2{,}5}{5} = 0{,}5$$

- Fair Water Quality (5.5 pH – 7.5 pH) has a membership level μFair (x), a linear function as follows:

$$\mu Fair(x)\{0\ if\ x \le 5{,}5\ \frac{-5{,}5}{6-5{,}5}\ if\ 5{,}5 \le x \le 6\ \frac{1\ if\ 6 \le x \le 7\ \frac{7{,}5-x}{7{,}5-7}\ if\ 7 \le x \le 7{,}5}{0\ if\ x \ge 7{,}5}\ x$$

Calculation example:

$$\mu Fair(6) = 1$$

- Good Water Quality (7 pH – 8.5 pH) has a membership level μGood (x), a linear function as follows:

$$\mu Good(x)\{0\ if\ x \le 7\ \frac{-7}{7{,}5-7}\ if\ 7 \le_x x \le 7{,}5\ \frac{1\ if\ 7{,}5 \le x \le 8\ \frac{8{,}5-x}{8{,}5-8}\ if\ 8 \le x \le 8{,}5}{0\ if\ x \ge 8{,}5}$$

Calculation example:

$$\mu Good(8{,}25) = \frac{8{,}5-8{,}25}{8{,}5-8} = \frac{0{,}25}{0{,}5} = 0{,}5$$

Calculation for *f*(water quality):

- Poor Water Quality of 2,5 pH in the range of 0 pH to 6 pH have a membership level *μPoor(x)* of 0.5
- Fair Water Quality of 6 pH in the range of 5,5 pH to 7,5 pH have a membership level *μFair(x)* of 1
- Good Water Quality of 8,25 pH in the range of 7 pH to 8,5 pH have a membership level *μGood(x)* of 0.5

3.Feeding Time membership

- New Feeding Time (6 - 12) has a membership level μNew (x), a linear function as follows:

  μ*New(x)*{ $_0$ $if \quad x$ $\leq 6 \; \frac{x-6}{6-8} \; if \; 6 \leq x \leq 8 \; 1 \; if \; 8 \leq x$ $0 \; if \; x \geq 12$

Calculation example:

μ*New*(8) = 1

- Long Feeding Time (11 - 18) has a membership level μLong (x), a linear function as follows: μ*Long(x)*{0 $if \quad x \leq 11 \; \frac{}{11-13} \; if \; 11 \leq x \leq 13 \; \frac{}{-11}$ $1 \; if \; 13 \leq x \leq 16 \; \frac{18-x}{18-16} \; if \; 16 \leq x \leq 18$ $if \; x \geq 18 \; 0$

Calculation example:

μ*Long*(17) = $\frac{18-17}{18-16} = \frac{1}{2} = 0{,}5$

Calculation for *f*(feeding time):

- New Feeding Time of 8 in the range of 6 to 12 have a membership level *μNew(x)* of 1
- Long Feeding Time of 17 in the range of 11 to 18 have a membership level *μLong(x)* of 0,5

Ground Rule Setting

After determining the input and output variables used, the next stage is to define the rules that determine the fuzzification output. Fuzzification rules are recommendations that allow for the representation of imprecise or unclear information in a system by transforming sharp and precise numerical data into fuzzy or linguistic concepts. In a fuzzy logic system, where an exact mathematical model may not fully reflect the uncertainty or ambiguity found in real-world data, these rules are crucial. Once the input and output variables are determined, the next step is to define the rules that determine the output of fuzzification.

Figure 4. Fuzzy Rule-Based

Water Temperature	Operand	Water Quality	Operand	Feeding Time	Fish Healthy
Low	AND	Poor	AND	New	Poorly Healthy
Low	AND	Poor	AND	Long	Poorly Healthy
Low	AND	Fair	AND	New	Healthy
Low	AND	Fair	AND	Long	Poorly Healthy
Low	AND	Good	AND	New	Very Healthy

Low	AND	Good	AND	Long	Healthy
Medium	AND	Poor	AND	New	Poorly Healthy
Medium	AND	Poor	AND	Long	Poorly Healthy
Medium	AND	Fair	AND	New	Healthy
Medium	AND	Fair	AND	Long	Healthy
Medium	AND	Good	AND	New	Healthy
Medium	AND	Good	AND	Long	Healthy
High	AND	Poor	AND	New	Poorly Healthy
High	AND	Poor	AND	Long	Poorly Healthy
High	AND	Fair	AND	New	Healthy
High	AND	Fair	AND	Long	Poorly Healthy
High	AND	Good	AND	New	Very Healthy
High	AND	Poor	AND	Long	Healthy

Based on fuzzy-based rules, the conditions used are where:

Water Temperature **25°C**(Low) and Water Quality **5.8 pH** (Poor) and Feeding Time **7 a.m** (New) which falls under the 1st rule "If **Water Temperature** is **Low** and **Water Quality** is **Poor** and **Feeding Time** is **New** then **Fish Healthy** is **Poorly Healthy**".

μ*WaterTemperatureLow(x)*$\{0\ if\ x \leq 0\ \frac{-0}{10-0}\ if\ 0 \leq x \leq 10\ \ 1\ if\ 10 \leq x \leq 20\ \frac{25-x}{25-20}\ if\ 20 \leq x \leq 25\ \ x\ \ if\ x \leq 0 25$

μ*WaterQualityPoor(x)*$\{0\ \ if\ \ x \leq 0\ \frac{x-0}{5-0}\ if\ 0 \leq x \leq 5\ \ 1\ if\ 5 \leq x \leq 5.5\ \frac{6-x}{6-5.5}\ if\ 5.5 \leq x \leq 6\ \ 0\ if\ x \leq 6$

μ*FeedingTimeNew(x)*$\{0\ \ if\ \ x \leq 6\ \frac{-6}{6-8}\ if\ 6 \leq x \leq 8\ \ 1\ if\ 8 \leq x \leq 10\ \frac{12-x}{12-10}\ if\ 10 \leq x \leq 12\ \ 0\ if\ x \leq 12\ \ x$

From these rules, the membership degree will be calculated for both conditions:

- Low Water Temperature membership degree = 1
- Poor Water Quality membership degree = 0,4
- New Feeding Time membership degree = 0,5

Next, use the AND operator to combine the membership degrees of the 3 conditions, Because the rule uses the AND operator, then use the smallest membership degree value of :

α = min (1, 0,4 , 0,5) = 0,4

Next, find out the output value by using a degree of membership α = 0,4 on the outputs chart. In this case, since the value α is 0,4, then the selected output is the Normal amount. The formula for calculating the α value in the rule is:

α = min (μ(Low Water Temperature), μ(Poor Water Quality), μ(New Feeding Time))

In this example, the result α is 0.4 because the smallest membership degree is 0.4. This explains how to use fuzzy rules to determine the health of fish based on Water Temperature, Water Quality, and Feeding Time.

Fuzzification

Fuzzification is a phase it involves the conversion of crisp input values into fuzzy representations. This process entails mapping crisp values into fuzzy sets and transforming them into fuzzy membership functions (Yanwari, 2017). The system under consideration utilizes four variables among others are, two input variables and two output variables. The input variables are water temperature each with three linguistic values, low, moderate, and high and water quality, poor, moderate, and good. The output variables are optimal feeding which have two linguistic values, long and new, then percentage of fish health have three linguistic values, unhealthy, healthy, and extremely healthy.

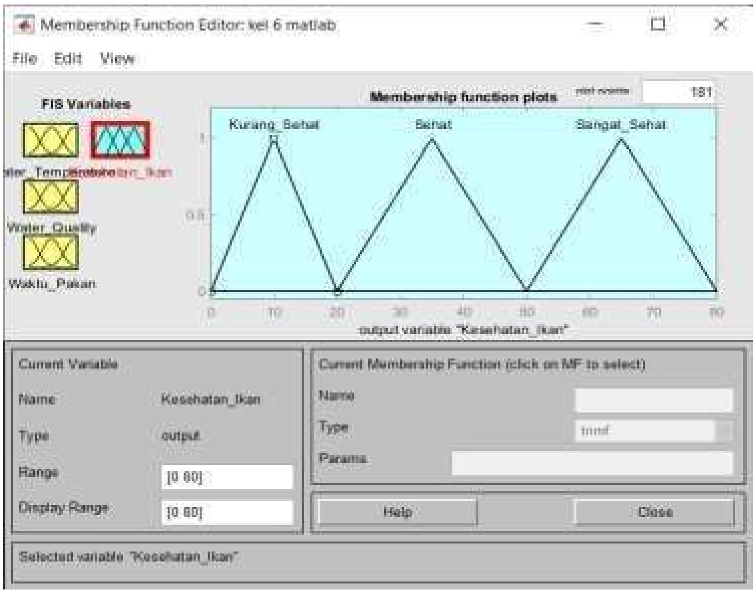

Figure 5. Fuzzy Membership Levels for the Output 'Healty fish'

$\alpha = \mu x$ Water Temperature $\cap\, \mu x$ Water Quality $\cap\, \mu x$ Waktu
$= \min (1 \cap 0{,}4 \cap 0{,}5)$
$= 0{,}4$

Output function membership set:

Here is the Membership Set of Output Functions in the "KurangSehat" Quantity Section:

$$_F(x) = \{0, x \leq 0 \;\; \frac{x-0}{10-0}, 0 < x < 4 \;\; 0{,}4, 4 \leq x \leq 16 \;\; \frac{20-x}{20-10}, 16 < x < 20 \;\; 0, x \geq 20$$

The Calculation

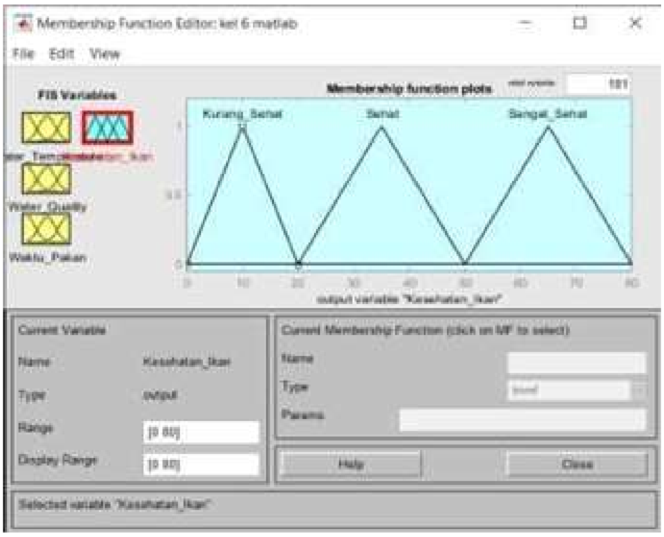

Figure 6. Fuzzy Membership Levels for the Output 'Healty fish'

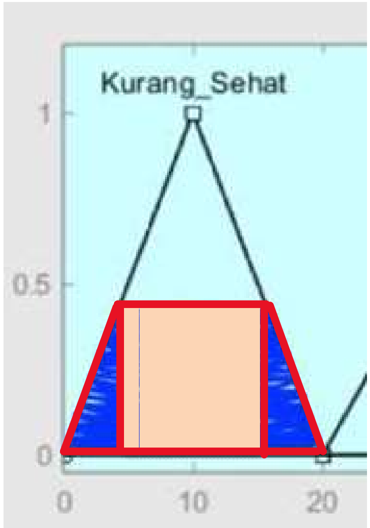

Figure 7. Output Variable "Unhealty fish"

In a case study of an unhealthy fish, the graph on the left, as shown in the above image, is used. It explains that there are 2 triangles and 1 rectangle that will be calculated.

x1 And x2

$\frac{1-a}{b-a}$ • x $= 0{,}4$

$\frac{x1-0}{10-0} = 0{,}4$

$\frac{x1}{10} = 0{,}4$

$x1 = 0{,}4 \text{ x } 10 = 4$

To find the value of x1, a fuzzy equation is used, assuming that x1 is in the interval [a, b] with a membership value of 0.4. Using a = 0 and b = 10, the equation is transformed to (x1 - 0)/(10 - 0) =

0.4. After solving it, the value of x1 is found to be 4.

- $\frac{c - x2}{c - b} = 0{,}4$

$\frac{20 - x2}{20 - 10} = 0{,}4$

$\frac{20 - x2}{10} = 0{,}4$

$20 - x2 = 10 \times 0{,}4$

$x2 = 16$

To find the value of x2, a fuzzy equation is used, assuming that x2 is in the interval [b, c] with a membership value of 0.4. Using b = 10 and c = 20, the equation is transformed to (20 - x2)/(20 - 10) = 0.4. After solving it, the value of x2 is found to be 16.

Calculating Area

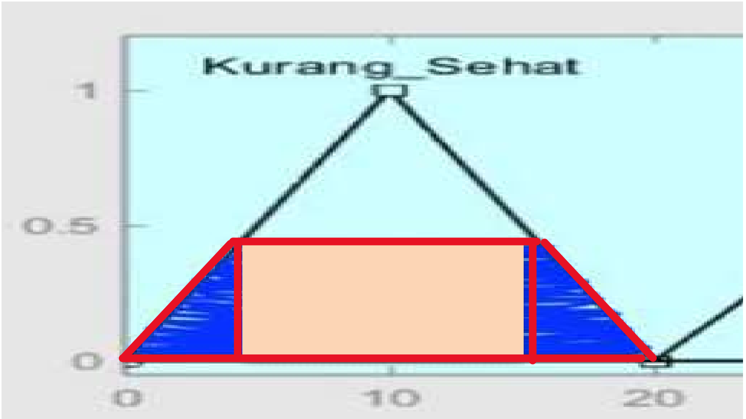

Figure 8. Output Variable "Unhealtyfish"

- $L_{D1}(Triangle) = \frac{1}{2}\, x\, a\, x\, t = \frac{1}{2}\, x\, 4\, x\, 0{,}4 = 0{,}8$
- $L_{D2}(Rectangle) = p\, x\, l = (16 - 4) x\, 0{,}4 = 4{,}8$
- $L_{D3}(Triangle) = \frac{1}{2}\, x\, a\, x\, t = \frac{1}{2}\, x\, (20 - 16) x\, 0{,}4 = 0{,}8$

  $Area = 0{,}8 + 4{,}8 + 0{,}8 = 6{,}4$

After obtaining the results for x1 (4) and x2 (16), the next step is to calculate the area under the membership function curve for each previously defined interval. For L_D1 (the first triangle), the area is calculated using the formula for the area of a triangle: 1/2 x base x height. With a base of 4 and a height of 0.4, the area of L_D1 is 0.8. Then, for L_D2 (the rectangle), the area is calculated using the formula for the area of a rectangle: length x width. With a length of 16 - 4 and a width of 0.4, the area of L_D2 is 4.8. Next, for L_D3 (the second triangle), the area is also calculated using the formula for the area of a triangle. With a base of 20 - 16 and a height of 0.4, the area of L_D3 is 0.8. After obtaining the area values for each interval, the total area under the membership function curve is 6.4, which is the sum of L_D1, L_D2, and L_D3.

Output Membership Set

- $x \leq 0 = 0$
- $0 < x < 4 = \frac{-}{-} = 0{,}1 x_b \quad a_a \quad x \rightarrow M_1$
- $4 \leq x \leq 16 = 0{,}4 \rightarrow M_2$
- $16 < x < 20 = \frac{-}{-} c_c \quad x_b \rightarrow M_3$
- $x \geq 20 = 0$

Thus, it has been calculated:

$-\quad -0$

$-\quad 10-0$

Moment

- $M_1 = \frac{x - a}{b - a} = \frac{x}{10-0} = 0{,}1x$

  $a_1 = 0$

  $b_1 = 4$

- $M_2 = 0{,}4 \quad a_2 = 4$

  $b_2 = \quad 16$

- $M_3 = \frac{c - x}{c - b} = \frac{20-x}{20-10} = \frac{20-x}{10} = 2 - 0{,}1x$

  $a_3 = 16$

  $b_3 = 20$

The membership values for each interval and the moment of each interval used in the fuzzy calculation have been determined.

Calculating Moment

$$M_1 \int_a^4 0,1x_{2+1} \cdot x \cdot dx \to 0,1x_2 = \int_0 F(x)\cdot x \cdot dx \to \frac{}{} \int_0 \int_0 dx \to (0,1x) \, dx \to \frac{}{2+1}$$

$$\int^4 \frac{0,1x^3}{3} \cdot dx \to \int_{00}^{4} 0,033x^3 \, dx$$

$$M_1 = [0,033(4)^3] - [0{,}033(0)^3]$$

$$= 2,112 - 03$$

$$= 2,112$$

For M1, the integration is performed from 0 to 4 of the membership function F(x) with a value of 0.1x. After integration, M1 is found to be 2.112.

$$M_2 \int_4 dx \to \int_4 dx \to \int_4^{16} 0,4x \, dx \to \int_4^{16} \frac{0,4x_{1 \; 1}}{1+1} dx \to$$

$$\int^{16} \frac{0,4x^2}{2} \cdot dx \to \int_{44}^{16} 0,2x^2 \, dx$$

$M_2 = [0,2(16)^2] - [0,2(4)^2]$

$= 51,2 - 3,2$

$= 48$

For M2, the integration is performed from 4 to 16 of the membership function F(x) with a value of 0.4. After integration, M2 is found to be 48.

$$M_3 = \int^{20} F(x) \cdot x \cdot \quad \int_{16}^{20} (2 - \quad \overset{20}{dx} \rightarrow \underset{1616}{\int} \quad 0,1x) \quad dx \rightarrow \quad 2x \quad 0,1x^2 \ dx \rightarrow$$

$$\int_{16}^{20} \frac{2x^{1+1}}{1+1} - \frac{0,1x^{2+1}}{2+1} \cdot \quad dx \rightarrow \int_{16}^{20} \quad x^2 \quad 0,033x^3 \ dx$$

$M_3 = [20^2 - 0,033(20)^3] - [16^2 - 0,033(16)^3]$

$= 136 - 120,832$

$= 15,168$

For M3, the integration is performed from 16 to 20 of the membership function F(x) with a value of 2 - 0.1x. After integration, M3 is found to be 15.168.

Centroid/Crisp Formula Calculating

$$Z = \frac{M^1 + M^2 + M3}{LD1 + LD2 + LD3}$$

$$= \frac{2,112 + 48 + 15,168}{0,8 + 4,8 + 0,8}$$

$$= \frac{65,28}{6,4}$$

$= 10,2$

After obtaining the values for M1, M2, and M3, the next step is to calculate the centroid using the formula Z = (M1 + M2 + M3) / (L_D1 + L_D2 + L_D3), where L_D1, L_D2, and L_D3 are the lengths of each membership function interval. After calculation, the centroid value is found to be 10.2.

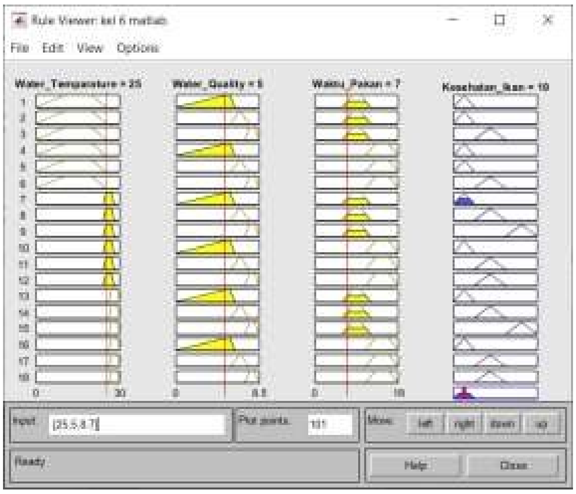

Figure 10.Matlab Rules Output

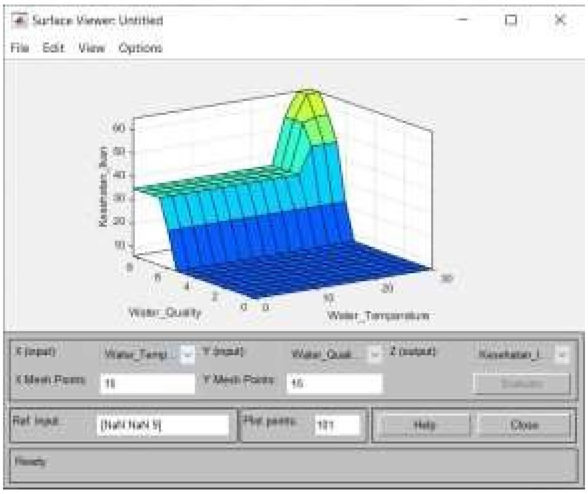

Figure 9. Surface Result from the Rules Created

In the above image, you can see the calculations from MATLAB where Water Temperature is 25°C, Water Quality is 6.5, Feeding Time is 15, and Fish Health is 21.3.

CONCLUSION

Automatic fish feeding systems that use fuzzy logic control have proven to be highly beneficial for aquaculture. Research indicates that these systems significantly enhance fish growth and health compared to traditional fixed-schedule feeders. By utilizing real-time data from sensors monitoring water temperature, pH, dissolved oxygen, and fish activity, these systems can adapt feeding amounts to mimic natural feeding patterns. This adaptive approach results in better fish growth rates and lower mortality.

The fuzzy logic control employs membership functions for variables such as water temperature, water quality, and feeding time. These functions classify the input data into linguistic categories like low, medium, high for water temperature, and poor, fair, good for water quality. By applying rules that combine these categories, the system determines the appropriate feeding amount and timing to optimize fish health.

For example, a scenario where the water temperature is 25°C (low), water quality is 5.8 pH (poor), and feeding time is 7 a.m. (new), results in a "poorly healthy" fish status according to the fuzzy logic rules. The membership degrees for each condition are combined using the AND operator, and the minimum value determines the output. This process ensures that the feeding system adjusts dynamically to changing conditions, providing optimal feeding and improving overall fish health.

Overall, the implementation of fuzzy logic in automatic fish feeding systems represents a significant advancement in aquaculture management, promoting better growth and health outcomes for fish through precise, data-driven feeding strategies.

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