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Adaptive Fuzzy in Agriculture System Horticulture Cultivation

Eddy Nurraharjo [a, *], Muji Sukur [a], Budi Hartono [a]

[a] *Faculty of Information Technology and Industry, Universitas Stikubank, Indonesia*

eddynurraharjo@edu.unisbank.ac.id, muji.sukur@edu.unisbank.ac.id, budihartono@edu.unisbank.ac.id

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ABSTRACT

The Industrial Revolution 4.0 rolled out all industrial sectors to enter the digital era. Digitalization of the agricultural sector, starting with the collaborative use of systems to detect natural phenomena related to temperature, humidity and light intensity, which affect crop production every year. Systems engineering in this research will approach a fuzzy logic algorithm, to help predict climate change and help operate adaptively. The recording of research data at a location of 188 meters above sea level, in a semi-greenhouse of oyster mushroom cultivation, has succeeded in obtaining a daily record of temperature, humidity and light intensity. This variable will be divided into two categories of hot and cold temperatures, high and low humidity, and dark and bright intensity. The Tsukamoto method, which is applied to this system algorithm, forms a fuzzy inference machine that is able to predict well for the natural input conditions of cultivation, namely temperature, humidity, and light intensity adaptively at each system output, namely atomizer sprayer pumps, fans, and lamps. Therefore, the Tsukamoto method can assist users in determining the output prediction well and is feasible to use on the system.

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* Corresponding author at:
Faculty of Information Technology and Industry, Universitas Stikubank
Jl. Tri Lomba Juang No.1 Semarang, 50241,
Indonesia
E-mail address: eddynurraharjo@edu.unisbank.ac.id

ORCID ID:
- First Author: 0000-0003-2015-5993
- Second Author: 0000-0001-8478-310X
- Third Author: 0000-0003-1494-8639

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1. Introduction

Agriculture is one of the dominant sectors in every aspect of a country's economic life [1]. Various cultivation areas have also been widely developed to support the economic stability of the world community. This technological engineering from upstream to downstream of agriculture has completed the management process. Current technology is applied with the use of advanced and modern electronic control systems, to automation systems that are able to speed up the cultivation process from pre-process to post-harvest [2].

Varied change factors that are the main highlight are phenomena that occur in natural factors of cultivation, where all aspects such as temperature, humidity, rainfall, soil contours, geography, height from sea level and so on [3]. It has the potential to help sort and select and allocate cultivation areas in areas that only meet the cultivation criteria and are limited. This will limit the area of cultivated land, the amount of specific agricultural production that exists, and the small potential of market production [4]. Oyster mushroom farming, for example, has standard operating standards and procedures, where variable factors of temperature, humidity and light intensity play a very important role in the growth, development and production of the harvest every year [5]

The potential of horticultural crops in several regions in Indonesia as recorded in data from the Annual Report of the Directorate General of Horticulture of the Ministry of Agriculture 2018, where data related to the target and realization of horticultural crop exports are related to the land area and volume of import exports of this mushroom cultivation [6]. The hope of continuous development in the long term is expected to make it a great potential for cultivators in the future.

Based on data from BPS RI 2018, it also informs the potential of mushroom cultivation which is still wide open and large, it is necessary to provide support for current technology and new agricultural modeling that can help in the long-term cultivation process [7][8][9].

2. Materials and Method

The results of supporting research in this article study were carried out by BPPT researchers, explaining in their journal articles that the requirements for growing mushrooms are influenced by several variable parameters including temperature, relative humidity, time, CO_2 content and light intensity [10]. This can be summarized in Table 1 [11].

Table 1 Measurement of Environmental Aspects of Cultivation

Environmental Aspects	Miselia Ph.	Primordial Ph.	Bodies Ph.
Temperature	24 – 29 ^oC	21 – 27 ^oC	21 – 28 ^oC
Humidity	90 – 100 %	90 – 100 %	90 – 95 %
Light Intensity	500 – 1000 lux	500 – 1000 lux	500 – 1000 lux
CO_2 content	5000 – 20000 ppm	< 1000 ppm	< 1000 ppm

Based on the data on environmental aspects above and the real conditions of the cultivation fields of several pilot areas in the Central Java region, it is concluded that other factors that affect the development and sustainability in this cultivation are the large number of consumers, producer farmers and their post-harvest processing capabilities. So researchers feel the need to limit system research only on their natural magnitude, with the following criteria [12].

Table 2 System Criteria

Environment	Value
Temperature	15 – 33 °C
Humidity	47 – 99 %
Light Intensity	80 – 800 lumens

The system criteria data in Table 2 will accumulate in the system and involve algorithms with process steps as shown in Figure 1. The system criteria data in Table 2 will accumulate in the system and involve algorithms with process steps as shown in Figure 1. The process begins with the detection of sensor data, then fuzzification of the data according to fuzzy criteria and rules on the inference machine, and a process of defuzzification of the outer value is carried out. The result of the decision is the execution of the system output load.

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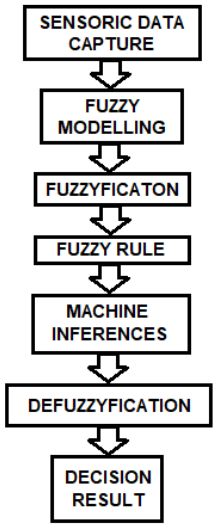

Figure 1 Flow Activity

The adaptive nature of the Tsukamoto fuzzy method approach, which wants to be applied to the research system results focuses on the conditioning system of the cultivation room, where the adaptive system is emphasized on its ability to respond to changes and disturbances that occur in its natural cultivation environment [13].

3. Design System

Several applications and uses of these three fuzzy basic theorems have been widely carried out, to the point of being able to compare studies on them [14]. The comparison of the three basic fuzzy theorems is carried out in the casuistic researchers, where sequentially the Tsukamoto method approach or theorem succeeds in placing the accuracy value in the middle between two other methods, namely Mamdani and Sugeno [15][16]. For this reason, the research on this occasion only focuses on the application of one of the mediators of the fuzzy theorem, namely the Tsukamoto fuzzy method.

The main activity flow is the design of the system algorithm, starting with the initialization of the necessary devices, followed by checking the data from the detection of physical variable changes from multi-sensors, namely temperature, humidity and light intensity. Data retrieval will be followed by recording, and processing prediction data using a fuzzy logic approach [17]. The value of the result will determine based on the already planned fuzzy rules in the form of an

IF-THEN function. More of these process activities are depicted in the diagram in Figure 2.

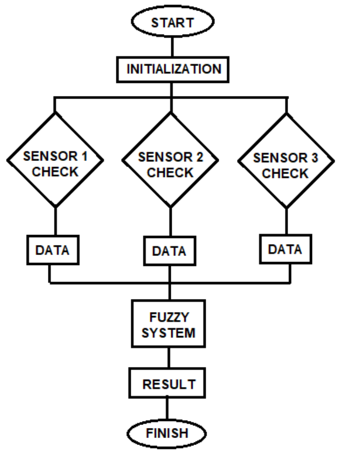

Figure 2 System Flow

4. Result and Discussion

This fuzzy logic was introduced for the first time by Prof. Lotfi Astor Zadeh [18]. Some of the problems that arise in this control/control system require Tsukamoto's fuzzy logic solution approach [14]. The application of this methodology is used in a variety of computing hardware, computing software and even a combination of the two [19].

ON/OFF, HIGH/LOW, 1/0, TRUE/FALSE logic is a logic analogy in general where it only has two conditions. The set of fuzzy (crisp) membership in this study can be represented [20], based on three variable data input sensors temperature, humidity and light intensity. While the two variables of system output are in the form of activating the atomizer sprayer pump machine, fan and lamp [21].

Representation of the fuzzy set membership function for temperature input variables, divided into two categories namely COLD and HOT, and is shown in Figure 3 [22].

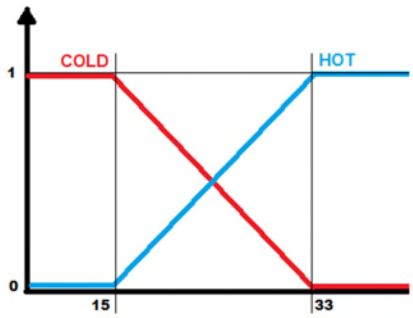

Figure 3 Temperature Membership Set

The COLD and HOT set membership functions of the temperature input variables of this Tsukamoto method can be expressed in Equation 1 and 2 as follows.

$$M_{HOT}[x] = \begin{cases} 0 & x \leq 15 \\ \frac{x-15}{18} & 15 \leq x \leq 33 \\ 1 & x \geq 33 \end{cases} \quad (1)$$

$$\mu_{COLD}[x] = \begin{cases} 1 & x \leq 15 \\ \frac{33 - x}{18} & 15 \leq x \leq 33 \\ 0 & x \geq 33 \end{cases} \tag{2}$$

Representation of the fuzzy set membership function for the humidity input variable, divided into categories as well namely LOW and HIGH, as in the Figure 4.

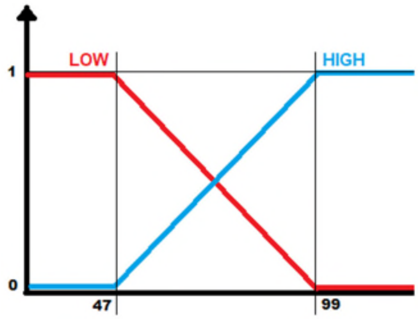

Figure 4 Humidity Membership Set

The membership function of the LOW and HIGH sets of the humidity input variables of this Tsukamoto method can be expressed in Equation 3 and 4 as follows.

$$\mu_{HIGH}[x] = \begin{cases} 0 & x \leq 47 \\ \frac{x - 47}{52} & 47 \leq x \leq 99 \\ 1 & x \geq 99 \end{cases} \tag{3}$$

$$\mu_{LOW}[x] = \begin{cases} 1 & x \leq 47 \\ \frac{99 - x}{52} & 47 \leq x \leq 99 \\ 0 & x \geq 99 \end{cases} \tag{4}$$

Representation of the fuzzy set membership function for light intensity input variables, which are divided into 2 categories, namely DARK and BRIGHT, and are depicted in Figure 5.

Figure 5 Light Intensity Membership Set

The membership function of the DARK and BRIGHT sets of the light intensity input variable of the Tsukamoto method can be expressed in Equation 5 and 6 as follows.

$$M_{BRIGHT}[x] = \begin{cases} 0 & x \leq 80 \\ \frac{x - 80}{720} & 80 \leq x \leq 800 \\ 1 & x \geq 800 \end{cases} \tag{5}$$

$$M_{DARK}[x] = \begin{cases} 1 & x \leq 80 \\ \frac{800 - x}{720} & 80 \leq x \leq 800 \\ 0 & x \geq 800 \end{cases} \tag{6}$$

Representation of the fuzzy set membership function of the system output variable i.e., the atomizer sprayer pump machine, divided into 2 i.e., ACTIVE and NON ACTIVE, and depicted in Figure 6.

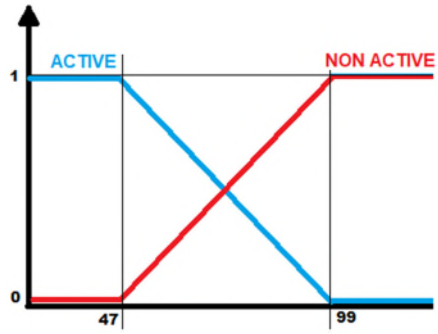

Figure 6 Set of Membership of the Atomizer Sprayer Pump Machine

The membership function of the ACTIVE and NONACTIVE sets of the output variables of this Tsukamoto method atomizer sprayer pump machine can be expressed in Equation 7 and 8 as follows.

$$\mathrm{M}_{\mathrm{NONACTIVE}}[x] = \begin{cases} 0 & x \leq 47 \\ \frac{x-47}{52} & 47 \leq x \leq 99 \\ 1 & x \geq 99 \end{cases} \quad (7)$$

$$\mu_{\mathrm{ACTIVE}}[x] = \begin{cases} 1 & x \leq 47 \\ \frac{99-x}{52} & 47 \leq x \leq 99 \\ 0 & x \geq 99 \end{cases} \quad (8)$$

Representation of the membership function of the fuzzy set of system output variables i.e., fan engine, divided into 2 i.e., STOP and PLAY rotating, as depicted in Figure 7.

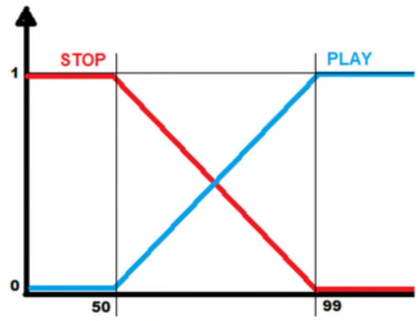

Figure 7 Set of Fan engine Membership

The STOP and PLAY rotating set membership functions of the Tsukamoto method fan engine system output variables can be expressed in Equation 9 and 10 as follows.

$$\mathrm{M}_{\mathrm{STOP}}[x] = \begin{cases} 1 & x \leq 50 \\ \frac{99-x}{49} & 50 \leq x \leq 99 \\ 0 & x \geq 99 \end{cases} \quad (9)$$

$$\mathrm{M}_{\mathrm{PLAY}}[x] = \begin{cases} 0 & x \leq 50 \\ \frac{x-50}{49} & 50 \leq x \leq 99 \\ 1 & x \geq 99 \end{cases} \quad (10)$$

Representation of the fuzzy set membership function of the system output variable i.e., the lamp, divided into 2 i.e., ON and OFF, as depicted in Figure 7.

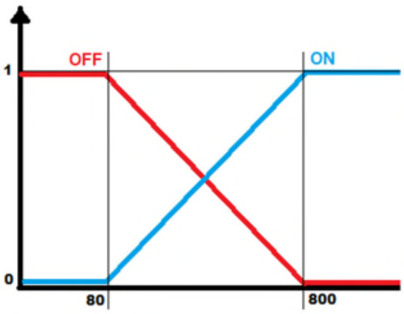

Figure 8 Set of Lamp Membership

The membership function of the set ON and OFF of the Tsukamoto method light system output variable can be expressed in Equation 11 and 12 as follows.

$$\mathrm{M_{OFF}}[x] = \begin{cases} 0 & x \leq 80 \\ \frac{x-80}{720} & 80 \leq x \leq 800 \\ 1 & x \geq 800 \end{cases} \tag{11}$$

$$\mathrm{M_{ON}}[x] = \begin{cases} 1 & x \leq 80 \\ \frac{800-x}{720} & 80 \leq x \leq 800 \\ 0 & x \geq 800 \end{cases} \tag{12}$$

Some fuzzy rules applied in the algorithm of this control system are based on some realization of their implementation [22] among them are:

ATOMIZER SPRAYER PUMP MACHINE

[R1] If the humidity is LOW, the temperature is HOT, the light intensity is BRIGHT, then the atomizer sprayer pump machine is ON.

[R2] If the humidity is HIGH, the temperature is HOT, the light intensity is BRIGHT, then the atomizer sprayer pump machine is OFF.

[R3] If the humidity is LOW, the temperature is COLD, the light intensity is BRIGHT, then the atomizer sprayer pump machine is ON.

[R4] If the humidity is HIGH, the temperature is COLD, the light intensity is BRIGHT, then the atomizer sprayer pump machine is OFF.

R5] If the humidity is LOW, the temperature is HOT, the light intensity is DARK, then the atomizer sprayer pump machine is OFF.

[R6] If the humidity is HIGH, the temperature is HOT, the light intensity is DARK, then the atomizer sprayer pump machine is OFF.

[R7] If the humidity is LOW, the temperature is COLD, the light intensity is DARK, then the atomizer sprayer pump machine is OFF.

[R8] If the humidity is HIGH, the temperature is COLD, the light intensity is DARK, then the atomizer sprayer pump machine is OFF.

FAN

[R1] If the humidity is LOW, the light intensity is DARK, then the fan STOPS.

[R2] If the humidity is HIGH, the light intensity is DARK, then the fan STOPS.

[R3] If the humidity is LOW, the light intensity is BRIGHT, then the fan STOPS.

[R4] If the humidity is HIGH, the light intensity is BRIGHT, then the fan PLAYS.

LAMP

[R1] If the light intensity is DARK, then the lamp is ON.

[R2] If the light intensity is BRIGHT, then the lamp is OFF.

If the real test case is as in Table 3, that if the current detected temperature is 29° Celsius, the humidity level reaches 65%, while the light intensity level reaches 600 lumens, then it can simply be tested by entering the magnitude of the variable value into the system until a defuzzification value of 'Z' is obtained based on Equation 13 [22].

$$Z = \frac{(\alpha 1xz1)+(\alpha 2xz2)+(\alpha 3xz3)+(\alpha 4xz4)}{(\alpha 1)+(\alpha 2)+(\alpha 3)+(\alpha 4)} \tag{13}$$

Table 3 The First Case Study

Set	Value
Temperature	29
Humidity	65
Light Intesity	600

Table 4 The Value of 'μ' Input Variable Membership Function

‘μ’ Input MFs					
Temperature		Humidity		Light Intensity	
COLD	HOT	LOW	HIGH	DARK	BRIGHT
0.22222	0.77778	0.65385	0.34615	0.27778	0.72222

Table 5 The Value of 'μ' Output Variable Membership Function

‘μ’ Output MFs					
Sprayer		Fan		Lamp	
ACTIVE	NON-ACT	STOP	PLAY	ON	OFF
0. 65385	0. 34615	0.69388	0.30612	0.27778	0.72222

The membership values in the input variables in Table 4, state that the temperature variable is in the HEAT category, the humidity variable is in the LOW category and the light intensity variable is in the BRIGHT category.

While the membership value in the output variable in Table 5, states that the atomizer sprayer pump is in the ON category, the fan is in the STOP category and the light is in the OUT category. The defuzzification value obtained as in table 9 follows.

Table 6 Defuzzyfication Results

Defuzzification ‘Z’		
Sprayer	Fan	Lamp
67.85714286	69.6538	600

The defuzzification results for the variables of atomizer sprayer pump machines and fans in Table 6 show that the weight of the operational value of the atomizer sprayer pump machine is 67.86 while for the weight of the operational value of the fan is 69.65. While the weight of the light intensity level is 600.

The second test, if the real test case is as in Table 7, that if the current detected temperature is 27° Celsius, the humidity level reaches 76%, while the light intensity level reaches 450 lumens, then the results obtained are as follows.

Table 7 The Second Case Study

Set	Value
Temperature	27
Humidity	76
Light Intesity	450

Table 8 The Value of 'µ' Input Variable Membership Function

'µ' Input MFs					
Temperature		Humidity		Light Intensity	
COLD	HOT	LOW	HIGH	DARK	BRIGHT
0.33333	0.66667	0.44231	0.55769	0.48611	0.51389

Table 9 The Value of 'µ' Output Variable Membership Function

'µ' Output MFs					
Sprayer		Fan		Lamp	
ACTIVE	NON-ACT	STOP	PLAY	ON	OFF
0. 44231	0. 55769	0.46939	0.53061	0.48611	0.51389

The membership values in the input variable in Table 8, state that the temperature variable is in the HEAT category, the humidity variable is in the HIGH category and the light intensity variable is in the BRIGHT category.

While the membership value in the output variable in Table 9, states that the atomizer sprayer pump is in the OFF category, the fan is in the PLAY rotating category and the light is in the OUT category. The defuzzification values obtained are as in Table 10.

Table 10 Defuzzyfication Results

Defuzzification 'Z'		
SPRAYER	FAN	LAMP
74.41880826	75.837	450

The defuzzification results for the variables of the atomizer sprayer pump machine and fan in Table 10 show that the weight of the operational value of the atomizer sprayer pump machine is 74.41 while for the weight of the operational value of the fan is 75.84. While the weight of the light intensity level is 450.

5. Conclusions

Adaptive fuzzy logic using the Tsukamoto method, in its depiction is divided into three main parts, namely the fuzzification process, inference machine modeling and the defuzzification process [23]. This method is also able to predict changes in temperature, humidity and light intensity values as the main variables in the conditioning of the natural environment, the cultivation of horticultural crops can respond adaptively and is able to run in accordance with the objectives of its implementation properly. The addition of multi variables as other input variables such as CO_2 pollution levels, as well as air pressure, and so on will be a challenge in the next development [3].

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