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Fuzzy Method Design for IoT-Based Mushroom Greenhouse Controlling

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Abstract— The ideal conditions for the oyster mushrooms growth are at a humidity of 65-75% and 29-31C during incubation, while the growth of stems should be at a humidity of 70-90% 29-32C. This ideal ecosystem is maintained by aeration and manual watering. Still, the results are not optimal in preventing damage to the mycelium during the incubation period, resulting in a decrease in crop yields. Automatic control has not created ideal conditions because air temperature and humidity regulation are only based on fans and sprayers that do not directly affect air conditions. Therefore, we need a method to manipulate the mushroom greenhouse space ecosystem, namely fuzzy logic, the application of fuzzy logic integrated with sensors, actuators, and microcontrollers with the Internet of Things to solve this problem. The results of the installation of fuzzy logic in the mushroom's greenhouse in this system can be seen from the fan's modulation response and the pump's duration. The test results of this control feature can manipulate temperature and humidity. Therefore, the oyster mushroom greenhouse produces an ideal state of 29.8C, the humidity of 68.97% RH, and the production has been proven to be optimal with an average daily harvest of 3.8kg.

Keywords—Fuzzy; Mushroom; Internet of Things

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I. INTRODUCTION

In Latin Volvariella volvacea, Oyster mushroom describes a category of mushrooms always cultivated by the population. Oyster mushrooms are tasty and have protein, nutrients, low prices, and people consume them as an alternative food. This oyster mushroom cultivation process requires accuracy and precision tolerance in regulating temperature and humidity that match the natural oyster mushroom habitat ecosystem to create optimal harvest output. One of the valuable roles to get optimal growth of oyster mushrooms is by maintaining air and humidity [1][2].

Usually, the temperature of oyster mushroom cultivation is maximally divided into two stages, namely: the incubation stage, which requires an air temperature of 29-31C with a humidity of 65-75%[3], the stage of making the body and fruit requires an air temperature of 29-32C with a humidity of 70-90% [4][5]. In the process of spraying and aeration of the greenhouse, oyster mushroom cultivators still manage the air and humidity manually., so for the incubation phase, the phase of making the mushroom body, it has not been able to achieve maximum conditions, not again when extreme transitions take place. So that it has an impact, the mushroom yields are shrinking because many mycelia are damaged during the incubation phase. Therefore, a fuzzy application procedure is needed to observe effective air temperature and humidity [6]. Fuzzy logic is always used in industry to control sensors, actuators, robotics.

For fuzzy logic to perform optimally in controlling it, a nodeMcu8266 microcontroller is needed, a DHT 11 sensor, an actuator in the form of a fan, and a pump. All devices will be connected to the internet of things (IoT) to facilitate the monitoring process. In previous studies [2][7][8], fuzzy logic can be integrated with IoT through a microcontroller into an intelligent system. It is reinforced by research [9][10] which states that fuzzy logic effectively regulates room temperature. Tsukamoto fuzzy is used in this study because of its advantages in dealing with the problem of uncertainty [11] and is more stable for multi-sensor data [12]. Several theoretical studies and IoT simulations [13] to produce a unified device require software integration with microcontrollers, sensors, and actuators to be mutually automated. While scientific studies on automatic control instrumentation[14], automatic temperature regulation can optimally increase oyster mushrooms' productivity.

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II. RESEARCH METHOD

The system development method used in this research is the Waterfall method. The waterfall method is a method that is carried out from a system carried out one by one and sequentially. Therefore, if the first step has not been done, so has the second one. If the second step has not been done, so has the third one, and so on. This organized method can anticipate errors in making a program [18].

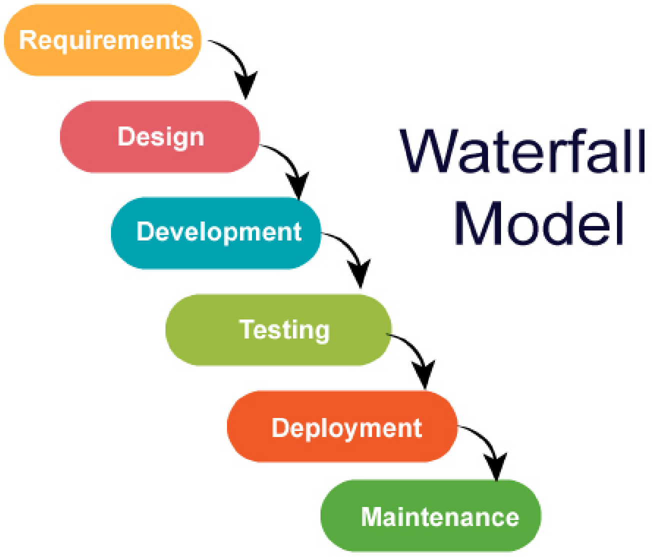

Figure 1. WATERFALL METHOD

Firstly, researchers plan a control system design for oyster mushrooms cultivation on mushrooms greenhouse using IoT based on fuzzy logic starting from processing preparation. Preparing tools, designing output variables and input variables, then determining the fuzzy set for each fuzzy variable. The fuzzification process is carried out by collecting data for each input variable, creating a membership function for each fuzzy set based on the smallest data value and the lowest data value for each fuzzy variable. Then, a rule is arranged for each input variable, as shown in Figure 2 Flowchart.

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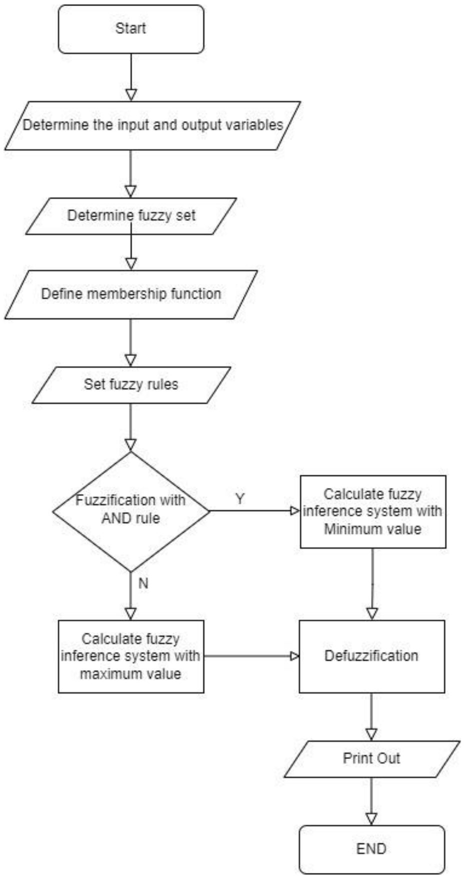

Figure 2. FLOWCHART FUZZY

A. Determination of Fuzzy Variable

This phase is an activity where fuzzy input and output value variables are formed based on the condition of the oyster mushroom greenhouse ecosystem. Parameter scores are obtained based on the value of sensor data processed through the fuzzification process, starting with creating a membership function as a weighted number for each input and output as in table.1.

Table 1. MODEL OF FUZZY RULE OYSTER MUSHROOM GREENHOUSE

Fuzzy Variables	Fuzzy Set	Score	Unit
Temperature	Cold	[0, 23]	Celsius degree
	Medium	[23, 30]	
	Hot	[30,100]	
Humidity	Dry	[0,40]	% (percen)
	Humid	[40, 60]	
	Wet	[60,100]	
Fan aeration	Off	[0,90]	humidity
	Slow	[80,180]	
	Fast	[180,255]	
Watering Motor	Off	[0, 40]	Milli liter
	Little	[300, 700]	
	Much	[600, 1000]	

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The membership variables in Table 1 have two inputs: temperature and humidity, then for the output of fan aeration and watering motor. The set membership function can be described as in Figure 3.

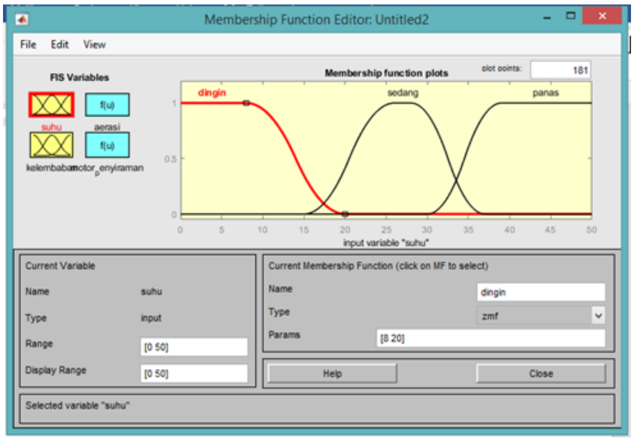

Figure 3. TEMPERATURE MEMBERSHIP FUNCTION.

The function of temperature membership in Figure.2 consists of condition variables. They are cold, medium, and hot. Meanwhile, the input humidity has three variables: dry, humid, and wet, as shown in Figure 4

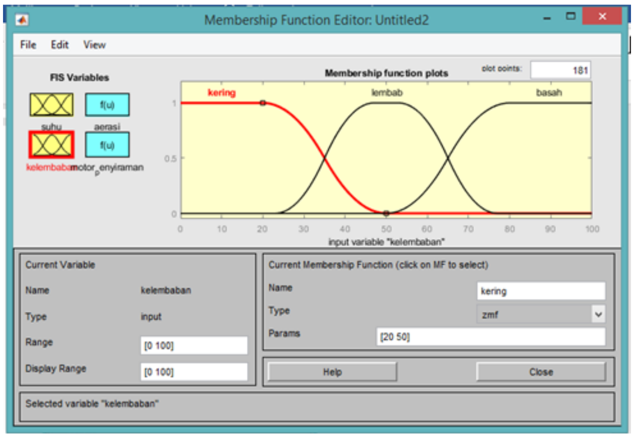

Figure 4.THE FUNCTION OF HUMIDITY MEMBERSHIP

Meanwhile, there are two conditions of membership set for the output or the actuator: fan aeration and spray pump. The fan performance process will be managed through pulse width modulation (PWM), which aims to control the condition of the fan rotation acceleration based on the value changes of fuzzy data to set the temperature of the mushroom greenhouse condition. At the same time, the spraying pump stabilizes the humidity.

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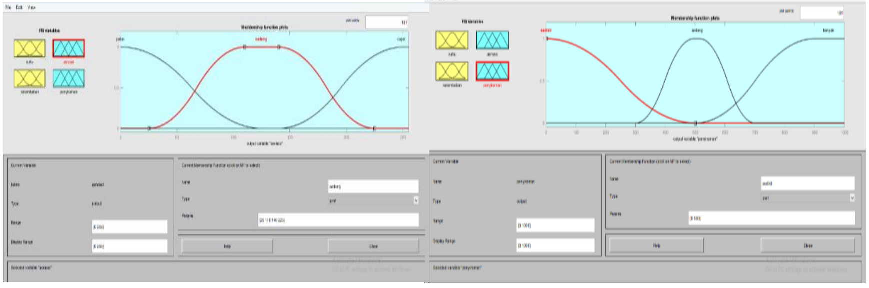

Figure 5. MEMBERSHIP FUNCTION OF FAN AERATION OUTPUT AND SPRAYING PUMP

B. The Formation of Rule Classification

Tabel 2. TABLE OF CLASSIFICATION RULE RESULTS

No	If	Antecedent	Then	Consequent
1		Cold Temperature and Low Humidity		Slow Fan and Much Watering
2		Cold Temperature and Medium Humidity		Slow Fan and Little Watering
3		Cold Temperature and High Humidity		Fast Fan
4		Medium Temperature and Low Humidity		Slow Fan and Little Watering
5		Medium Temperature Medium Humidity		Fan Off Watering Off
6		Medium Temperature High Humidity		Fast Fan Little Watering
7		Hot Temperature Low Humidity		Fast Fan Much Watering
8		Hot Temperature Medium Humidity		Fast Fan Much Watering
9		Hot Temperature High Humidity		Fast Fan Little Watering

C. The Formation of Rule Classification

The manufacture of the prototype device consists of the functional requirements of the hardware as a gate for processing automation of sensor data values and transmitting commands to the actuator. Hardware requirements as in Table 3.

Tabel 3. HARDWARE SPECIFICATION

No	Hardware	Hardware Types	Functional System
1	Microcontroller	NodeMcU esp 8266	Device control and controller and data transmitted sensor through Wifi
2	Transducer	DHT 11	Sensors of temperature and humidity
3	Actuator	Fan dan nozzle pump	Output for controlling temperature and humidity.

As a hardware unit in Table.3, the software is needed as the controlling brain to perform automation. This software is built using C language, which is embedded fuzzy in the form of an algorithm, with the help of the Arduino IDE compiler. So that end users can monitor then add database interactions and web-based applications, which are built with the PHP language.

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III. RESULT AND DISCUSSION

After the entire system on the prototype has been built, as shown in Figure 6, testing is carried out to find out how well fuzzy can manage the oyster mushroom greenhouse ecosystem. In addition, the operational feasibility process between the sensor and microprocessor also needs to be benchmarked.

Figure 6. PROTOTYPE OF HARDWARE AND SOFTWARE

A. System Test

Testing the actuator with PWM modulation connected to NodeMcu8266 which has embedded fuzzy logic, then a 12V power supply is provided to the fan motor.

Tabel 4. THE RESULTS OF TESTING PWM FAN ACCUATOR

Temperature (C)	Cold Condition	Medium Condition	Hot Condition	PWM Fan
23,8C	1,00	0,00	0,00	24,72
24,5C	1,00	0,20	0,00	45,23
24,7C	1,00	0,80	0,00	47.35
26,7C	0,00	0,20	0,00	71.22
27,5C	0,00	1,00	0,00	72,46
28,4C	0,00	0,31	0,20	127,22
28,9C	0,00	0,28	0,80	135,24
29,7C	0,00	0,78	1,00	180,31
33,6C	0,00	0,40	0,30	183,21
35,2C	0,00	0,00	1,00	197,11

Overall, at a temperature range of 23C-35C, fuzzy can provide control input with a fan rotation PWM modulation response to maintain the temperature in the oyster mushroom greenhouse ecosystem. The variable area surface temperature and humidity results are shown in Figure 7.

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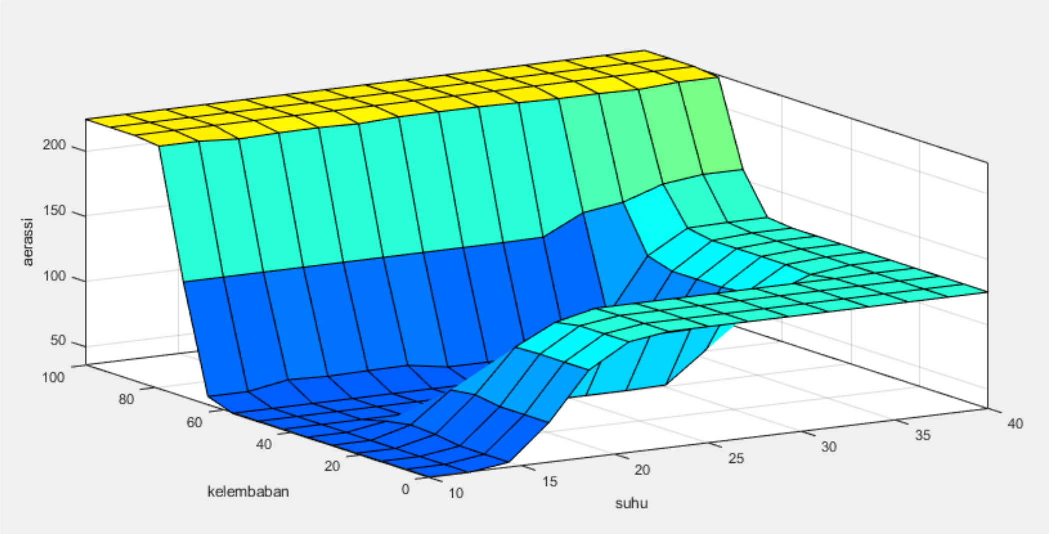

Figure 7. RANGE VARIABLE OF AREA, TEMPERATURE, AND HUMIDITY

While the testing result on greenhouse aeration obtained a humidity range of 58%-98%, the actuator can respond to fuzzy input commands through the nodemcu8266 microprocessor automation process, with a nozzle pump duration of 0.3-1.5 seconds. Test results as shown in Table. 5.

Table 5. TESTING RESULTS OF NOZZLE PUMP AERATION

RH(%)	Dry Condition	Humid Condition	Wet Condition	Pump On
58,3	1,00	0,00	0,00	1,42 second
68,4	1,00	0,00	0,00	1,37 second
68,8	0,90	0,30	0,00	1,32 second
69,1	0,70	0,45	0,00	1,13 second
69,8	0,35	0,78	0,20	0,71 second
74,6	0,00	0,90	0,00	0,51 second
78,3	0,00	0,96	0,00	0,56 second
83,3	0,00	1,00	0,31	0,34 second
85,5	0,00	1,00	0,45	0,38 second
90,2	0,00	0,00	1,00	0,3 second

B. The Analysis of Feasibility Control

The feasibility analysis process for the performance of fuzzy logic integrated into the controller is carried out when the mushroom baglog incubation begins to appear, the pileus pinhead of the oyster mushroom until the mushroom spore mycelium begins to expand and can be harvested. The fuzzy logic results can manipulate environmental factors for the growth of oyster mushrooms, especially the temperature of the greenhouse mushroom ecosystem. IoT-based fuzzy controllers can control temperatures in the average range of 29.8C with an average harvest of 3.9kg per day. As in table 6.

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Table 6. FEASIBILITY RESULTS AND HARVEST RESULTS

Days	Before fuzzy control		After fuzzy control	
	Greenhouse Temperature	Harvest (kg/days)	Greenhouse Temperature	Harvest (kg/days)
1	35 C	1	33 C	3
2	33 C	2	31 C	3
3	33 C	2	32 C	3
4	34 C	1	32 C	3
5	34 C	1	28 C	4
6	33 C	2	29 C	5
7	35 C	1	29 C	5
8	34 C	1	27 C	4
9	33 C	2	28 C	5
10	35 C	1	29 C	4
Average	Average (33,9)	1,4	Average (29,8)	3,9

The results of the fuzzy logic performance in the controller on the daily harvest output are as shown in Figure 7.

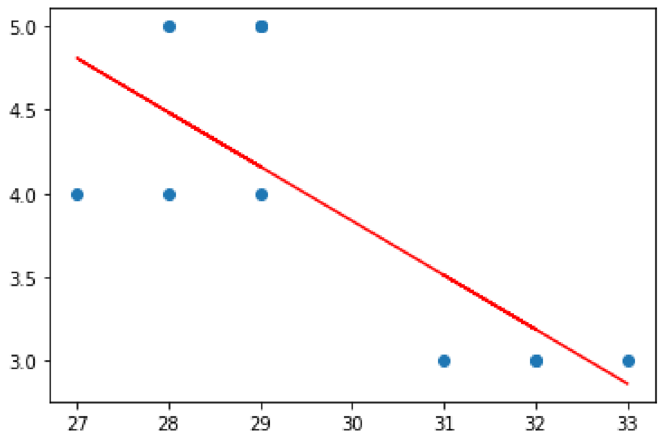

Figure 8. FUZZY CONTROL MANIPULATES TEMPERATURE ON HARVEST/DAY

Figure.8 shows that the fuzzy performance in manipulating temperature increased the daily harvest results of oyster mushrooms.

IV. CONCLUSION

T The fuzzy logic obtained a humidity in the range of 58%-98% with a nozzle pump duration of 0.3-1.5 seconds on temperature and humidity control with IoT testing results on greenhouse aeration. Overall at a temperature range average 33,9C-29,8C. It is concluded that this control can manipulate temperature, humidity in the oyster mushroom greenhouse in ideal conditions produce a perfect state of 29.8C, the humidity of 68.97% RH, and production has been

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proven to be optimal with an average daily harvest of 3.8kg. While for further development, it is necessary to create a more compact integrated circuit board path.

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