Fuzzy Logic Implementation In Internet Of Things Technology For Foging Greenhouse Plants

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Abstract

Misting of plants in a greenhouse has an important role in maintaining the environmental humidity that plants need. Obstacles faced to maintain the humidity of the plant environment is the use of a thermometer as a measuring tool and misting is still manual. Based on these problems, this research presents an automatic misting system for plants in a greenhouse using the fuzzy logic method. The process of taking data on the temperature and humidity of the plant environment in the greenhouse is from the DHT11 sensor value which is read by the microcontroller to be stored in the Firebase cloud database, the temperature and humidity data in the cloud database is sent and displayed in real-time by an android application built with the MIT tool App Inventor 2. Apart from displaying temperature and humidity data from Firebase, the Android application also processes it using fuzzy logic to produce PWM (Pulse Width Modulation) values to set the fog time. The fuzzy logic method was chosen to map input data problems to output data in conducting fog control. From the sensor test, the results obtained from the comparison of DHT11 sensor readings have an average error of 2.73%. The duration of watering is carried out using Fuzzy logic, the total amount of watering in a day is 2,500 ml of water with a duration of 75 seconds, so that the fogging with the fuzzy logic method is in accordance with the conditions needed in the greenhouse room.

Keywords: fuzzy logic, IoT, Foging, Misting, greenhouse, plants.

I. INTRODUCTION

Environmental temperature and humidity factors are very influential on the growth and development of plants in greenhouse spaces [1][6][8]. The temperature required for the growth of mycelium is 28-30°C and humidity is 70-85%, while for the formation of fruiting bodies it is 22-26°C and humidity is 80-90%. Then automation of condensation is needed, because condensation is still done manually, and condensation is carried out when the data results from the temperature on the thermometer > 60°C [2][7].

Efforts to develop a hydroponic plant watering monitoring and control system such as that carried out by Prayitno use Blynk, the system built is tasked with monitoring temperature and humidity information through sensor devices connected to the LCD and the Blynk application [9]. This system uses the RTC (Real Time Clock) as a time marker in setting the watering control and does not use the method as a procedure to solve the problems developed. In addition, the microcontroller used is not integrated with the wi-fi module, so it requires additional components to connect with the Blynk application.

Research that implements the field of soft computing is [3][4][5], they develop an automatic temperature and humidity control system using fuzzy logic, design a monitoring system by implementing fuzzy logic as a control. However, this system only monitors by looking at the display on the LCD screen, without using additional devices as remote monitoring such as IoT (Internet of Things).

In this research a temperature and humidity monitoring device was developed using an Android application and PWM (Pulse Width Modulation) control to adjust the length of time for fogging by applying the fuzzy logic method in the process of determining PWM as computing with words when the information provided is too imprecise or vague. Utilization of the Node-MCU microcontroller device which has been integrated with the ESP8266 wi-fi module by configuring the program so that it can connect to the firebase cloud database for storing the results of reading temperature and humidity data.

The implementation of the fogging device is carried out in the greenhouse room with the Node-MCU ESP8266 microcontroller that uses a DHT11 sensor, an actuator with a Relay module, an LM2596 step down and a DC pump. Users can interact with smartphone devices through Android applications developed with MIT App Inventor.

II. RESEARCH METHODS

A. Tools and materials

It is very important to prepare research tools and materials as a condition for research to run well. The tools and materials that need to be prepared for this study are sensors, microcontrollers, cloud databases, IDE (Integrated Development Environment) and the Paludarium Terrarium 5 Mist Nozzle Misting Package, which consists of:

- Sensor DHT11,
- Microcontroller Node-MCU ESP8266,
- Firebase Database Cloude Server,
- Smartphone Android,
- Arduino IDE dan Library,
- Relay Modul,
- MIT App Inventor,
- 1 pcs PU Connector, Elbow 6 mm,
- 4 pcs PU Connector, Tee 6 mm,
- 5 pcs Nozzle Slip Lock 0.3 mm,
- 1 pcs Diaphragm Pump 12V DC 3A, 80 Psi 3L/Min,
- 1 pcs Adaptor AC 220 V ke DC 12 V, 3 A,
- 1 pcs Jack DC (terpasang di pompa),
- 1 pcs Mini FIlter (untuk sumber air dari wadah),
- 1 pcs PU Connector 18mm Drat Dalam ke Selang PU 6 mm,
- 2-meter Selang PVC Hitam 8x11 mm (selang air masuk),
- 5-meter Selang PU Hitam 6x4 mm (selang ke nozzle),
- Stop kontak listrik.

B. System Architecture Design

At the system architecture design stage, the architecture and workflow of the Greenhouse Plant Fogging system will be designed. An overview of the architecture of the Greenhouse Plant Misting system can be seen in **Figure 1**.

The architecture of the Greenhouse Plant Misting system in Figure 1 can be seen that the INPUT comes from Temperature and Humidity data taken from the DHT11 sensor. The Node-MCU ESP8266 microcontroller reads temperature and humidity data via the DHT11 sensor and sends the data to the cloud database server (Firebase) for storage. Then in real-time the mobile application (android) displays temperature and humidity data from the cloud database, besides that the android application also processes with Fuzzy Logic to produce PWM (Pulse Width Modulation) data output which is also stored on the cloud database server, by this PWM Microcontroller converted into time in seconds to control the water pump through the relay module to create fog in the greenhouse.

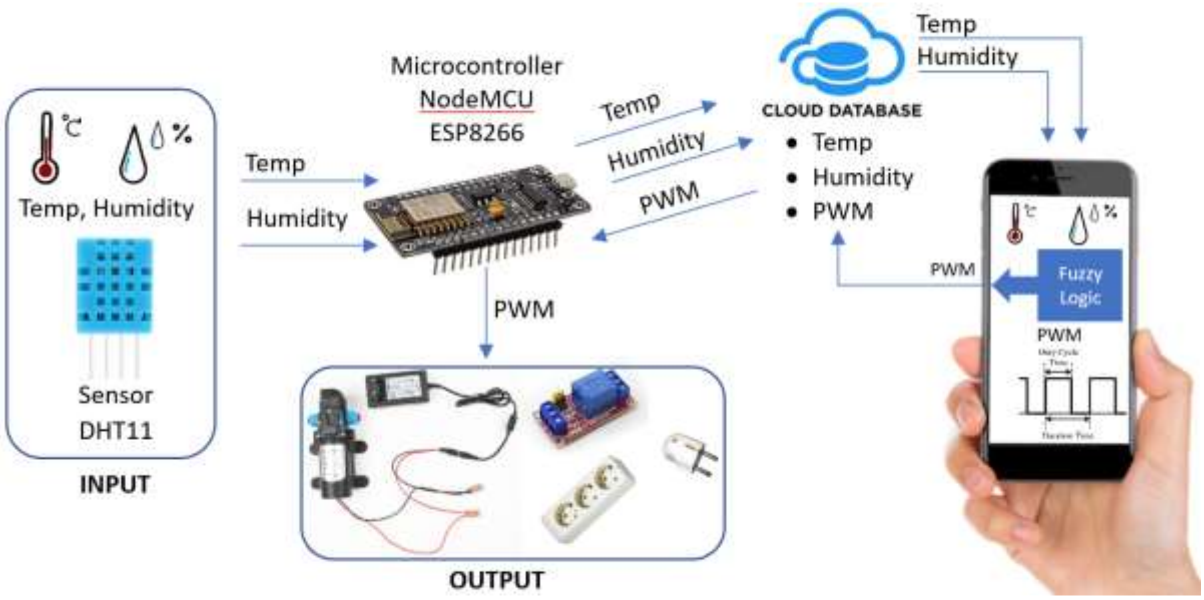


Figure 1. Greenhouse Plant Foging System Architecture

C. Software Design

Software design consists of designing control programs and interfaces. Making control through the program begins with designing the system flowchart as shown in Figure 2. The system has a choice of auto or manual mode settings on the interface. Manual mode provides the option to turn on and turn off the fogging water pump with user control via a button on the application. The button is an ON-OFF toggle which simultaneously shows the status of the actuator being active or deactivated. While the auto mode starts by setting the set point. Set point can be set via a slider or database. The slider provides the option to set the temperature and humidity parameter set point according to the configuration by the user but has a minimum and maximum limit. Configuration through the database is done by selecting options from the list that is displayed. Then the set point data will be stored in the database and sent to the microcontroller for controlling the misting pump.

Pump control automatically uses fuzzy logic, starting with reading the temperature and humidity parameters stored in the database. Furthermore, the fuzzification process is carried out and converted into linguistic variables through the membership function. Then an evaluation is carried out through the rules that are made and a defuzzification process is carried out to get PWM data as output and converted by the microcontroller into seconds of time. The PWM data is duration data (in seconds) which is used to control the length of time the pump is on to fog.

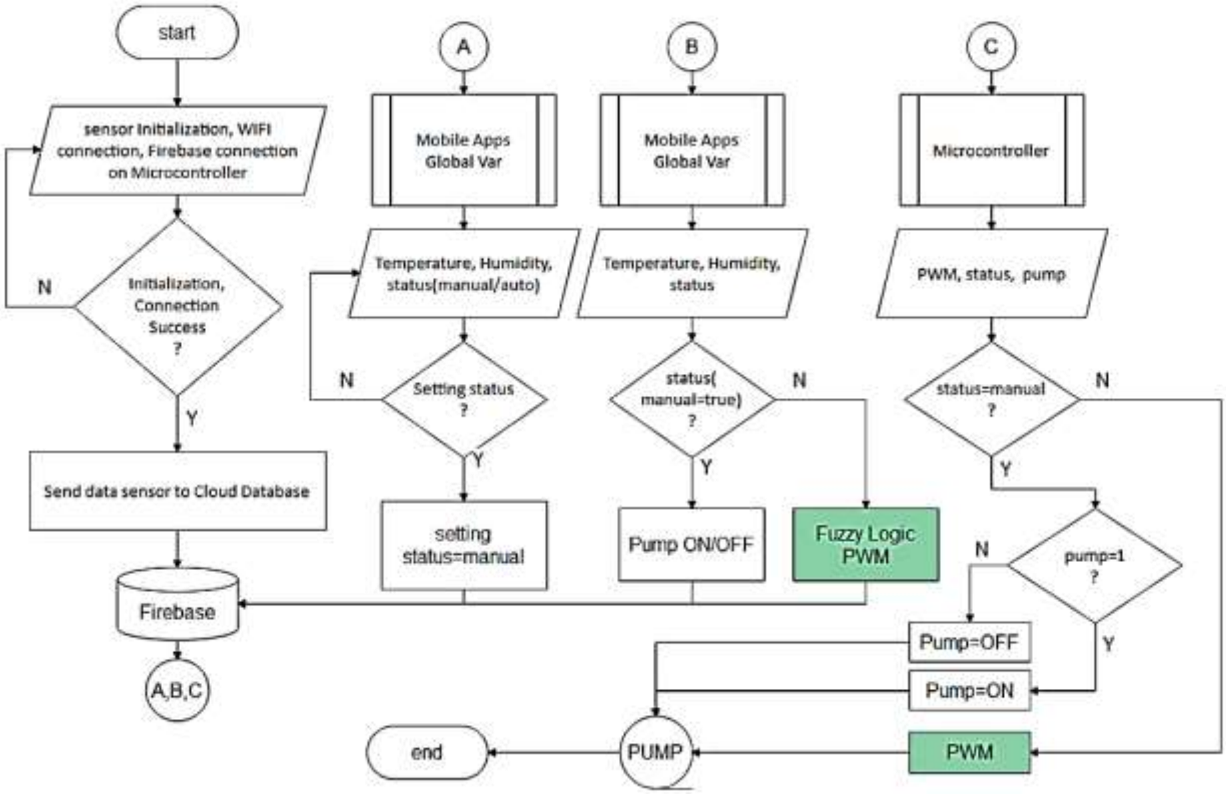
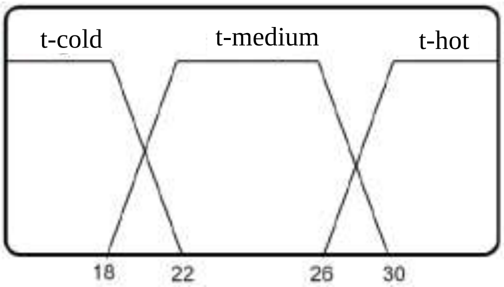


Figure 2. Greenhouse Plant Foging System Flowchart

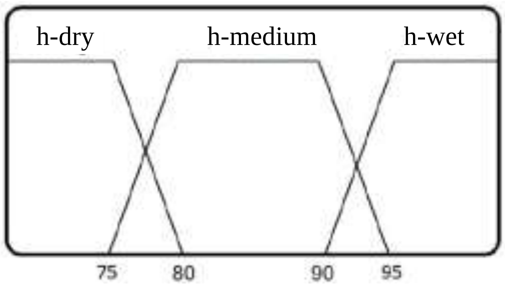
D. Fuzzy Logic Design

At Application of fuzzy logic as a control system in this Greenhouse Plant Misting System, because fuzzy has a mathematical concept that is suitable for determining the rule (output). Before the execution of Greenhouse Plant Fogging is carried out, there are fuzzy stages in mapping input variables to output variables. The design of fuzzy logic in the Greenhouse Plant Misting System has three stages in accordance with the provisions, namely the fuzzification stage, the formation of fuzzy rules (Inference) stage, and the defuzzification stage. These stages are described as follows:

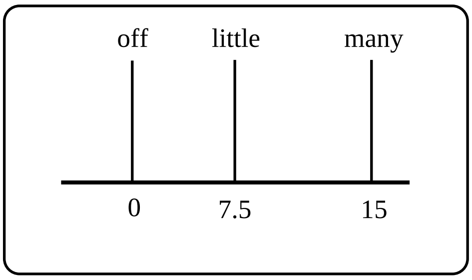
Fuzzification stage, this stage is carried out to convert crisp (numeric) values into fuzzy sets using the membership function. In designing this system, it uses two inputs (data from the DHT11 sensor), namely humidity (in %) and temperature (in ºC). The desired output is the duration of the water pump (in minutes) which is represented by the PWM (Pulse Width Modulation) value. This fuzzification stage serves to map the sensor membership set, because each temperature and humidity sensor value has a different membership. **Figure 3** shows the input membership set (temperature and humidity sensors), the membership values of the temperature and humidity sensors are divided into 3, namely the temperature has cold, medium, and hot membership. Meanwhile humidity has dry, medium and wet membership.



(a) Temperature Membership Function



(b) Humidity Membership Function



(c) Output Membership Function (in seconds)

Figure 3. Input (Temperature, Humidity sensor) and Output Membership Functions

The Fuzzy Rule Formation Stage or the Inference stage, this stage is made based on the desired state (according to any reference). Inference serves to determine fuzzy rules. The data obtained from the fuzzification stage in the form of membership values for temperature and humidity sets will be summed up to determine the appropriate fuzzy rules, as shown in TABLE I below:

TABLE I. INFERENSI RULE FUZZY

Temperature	***Humidity***	***Rule***
t-cold	h-dry	Rule0
t-cold	h-medium	Rule1
t-cold	h-wet	Rule2
t-medium	h-dry	Rule3
t-medium	h-medium	Rule4
t-medium	h-wet	Rule5
t-hot	h-dry	Rule6
t-hot	h-medium	Rule7
t-hot	h-wet	Rule8

As stated in TABLE I above, there are 9 fuzzy rule inferences, the number of 9 rules is obtained from the set of membership functions at the fuzzification stage. TABLE I above also shows that there are 3 linguistic values for input humidity, namely dry, normal, and wet. Meanwhile, in the input temperature there are 3 linguistic values, namely cold, medium, and hot. Fuzzy rules are created with IF – THEN functions. For example: IF dry humidity AND Cold Temperature THEN a little misting or the water pump starts briefly. These fuzzy rules will be forwarded to the next stage, namely defuzzification, as the final stage in determining the watering order. In this system the fuzzy rules are determined as in Table II below:

TABLE II. FUZZY RULE

Fuzzy Rule		Temperature		
		t-cold	***t-medium***	***t-hot***
Humidity	***h-dry***	little	little	many
	h-medium	off	off	little
	h-wet	off	off	off

As stated in **TABLE II** above, the role of fuzzy logic as a determinant of fog control. There is a membership function in executing fogging off, a little and a lot. Off fogging is a condition of not doing misting (pump off), a little misting means carrying out misting with 500 ml of water and a lot of misting with 1000 ml of water.

The last stage is the Defuzzification stage which is the stage in designing fuzzy logic. This stage is the input confirmation stage. This assertion is obtained from fuzzy rules, while the output is a number in the domain of the fuzzy set. The defuzzification process in this study will seek the maximum value in the crisp set between 0 and 1. As stated in **TABLE III** below, the fogging process has 3 parts, namely a little, off and many.

TABLE III. DEFUZZIFIKASI PENGKABUTAN

Rule	***Foging***
Rule0	little
Rule1	Off
Rule2	Off
Rule3	little
Rule4	Off
Rule5	Off
Rule6	many
Rule7	little
Rule8	Off

III. SYSTEM IMPLEMENTATION AND DISCUSSION RESULTS

In this process hardware components are assembled and assembled according to their respective functions so that the system can work properly. The assembly process is carried out in accordance with Figure 1. Greenhouse Plant Fogging System Architecture. Fuzzy logic is processed in the Android application after receiving input data on humidity and temperature in the plant environment in the greenhouse. The following is a test of the Greenhouse Plant Foging System.

A. *DHT11 Sensor Input Testing*

Testing on the microcontroller input section aims to calibrate and measure the accuracy of the DHT11 temperature and humidity sensor readings with a thermometer and hygrometer.

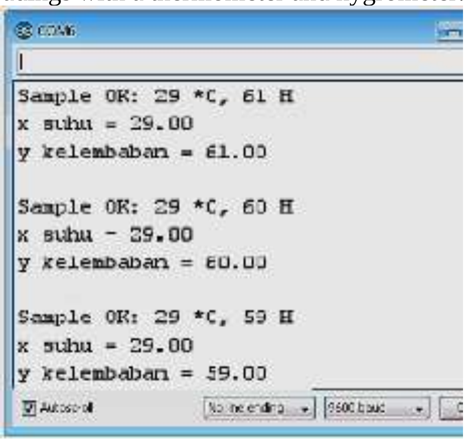


Figure 4. Testing Data Input (DHT11 sensor) temperature and humidity on the Arduino IDE Serial Monitor display

The steps for testing the input data (sensors) after being assembled by connecting to the Node-MCU ESP8266 microcontroller, is to provide electric power via the micro-USB port. Writing program code utilizes the Arduino IDE which is equipped with a library for micro-controllers. The system is then run to observe the results of temperature and humidity sensor data displayed on the serial monitor¸ console Firebase cloud database and Android application. The Serial Monitor display on the Arduino IDE as shown in Figure 4 above shows the results of testing the temperature and humidity sensors which were successfully read by the microcontroller.

Determining the use of sensors can be determined by calculating the error value and the percentage of error values from the sensor reading calibration (DHT11) with the testing instrument, if the error value is known then the sensor can be declared fit for use. In determining the error value, the following formula applies [10]:

$$\text{Error} = \frac{(X - Xi)}{X} \quad (1)$$

$$\text{Error (\%)} = \frac{(X - Xi)}{X} * \mathbf{100\%} \quad (2)$$

annotation:

X = actual value (standard measuring tool = thermometer)

Xi = measured value (value from prototype=DHT11 sensor)

TABLE IV. DHT11 SENSOR CALIBRATION TEST

Days to-	*Times*	*DHT11 (ºC)*	*Thermometer (ºC)*	*Error*	*Error (%)*
1	±06.00	20	20	0.0000	0.00%
	±12.00	28	29	0.0667	6.67%
	±18.00	26	27	0.0370	3.70%
2	±06.00	21	21	0.0000	0.00%
	±12.00	28	29	0.0345	3.45%
	±18.00	27	28	0.0357	3.57%
3	±06.00	20	20	0.0000	0.00%
	±12.00	28	29	0.0345	3.45%
	±18.00	26	27	0.0370	3.70%
4	±06.00	21	22	0.0455	4.55%
	±12.00	29	30	0.0333	3.33%
	±18.00	27	28	0.0357	3.57%
5	±06.00	20	20	0.0000	0.00%
	±12.00	28	29	0.0345	3.45%
	±18.00	26	27	0.0370	3.70%
6	±06.00	21	21	0.0000	0.00%
	±12.00	28	29	0.0345	3.45%
	±18.00	27	28	0.0357	3.57%
7	±06.00	20	20	0.0000	0.00%
	±12.00	28	29	0.0345	3.45%
	±18.00	26	27	0.0370	3.70%
			Average Error	**0.0273**	**2.73%**

As stated in **TABLE IV** above, the average sensor device comparison error is 0.0273 or 2.73%. The sensor accuracy can be said to be good, although there are still errors between the DHT11 sensor readings and the thermometer measuring device. Sensor testing was carried out for 7 days with testing 3 times a day in the morning, afternoon, and evening.

B. Fuzzy Logic Process Testing

Fuzzy Logic Process Testing was carried out to determine the comparison of the results of manual watering with automatic watering using the fuzzy logic method. So that the difference in duration and amount of water released is known. The steps for testing the fuzzy logic method by placing the system in a greenhouse room. The system is then operated, and the temperature and humidity sensor values obtained will be converted into a set of membership vectors for cold, medium, and hot on dry, normal, and wet humidity sensors. Then observe the data from sensor readings and fog, the data results are recorded for analysis and entered in the test results table. In accordance with the output membership function, misting is off, the pump does not turn on, while slightly misting the pump runs for 7.5 seconds with 250 ml of water and multiple misting of the pump turns on for 15 seconds by releasing 500 ml of water (according to the water discharge reference stated on the pump).

TABLE V. PENGUJIAN PROSES LOGIKA FUZZY

No	***Waktu***	***Input Sensor DHT11***		***Thermometer***	***Output***		
		Temperature	***Humidity***		***Fuzzy Rule***	***Pompa menyala (Detik)***	***Debit Air (mili liter)***
1	±08.00	21	87	22	Rule1	0	0
2	±09.00	23	86	24	Rule4	0	0
3	±10.00	25	82	26	Rule4	0	0
4	±11.00	26	79	27	Rule3	7.5	250
5	±12.00	27	78	28	Rule6	15	500
6	±13.00	28	75	39	Rule6	15	500
7	±14.00	28	77	30	Rule6	15	500
8	±15.00	26	77	27	Rule3	7.5	250
9	±16.00	22	82	23	Rule3	7.5	250
10	±17.00	20	86	21	Rule0	7.5	250
Jumlah						**75**	**2500**

The data presented in TABLE V, the total amount of watering in a day is 2,500 ml of water with a duration of 75 seconds.

IV. CONCLUSION

This study proposes the application of fuzzy logic for fogging systems in greenhouse rooms so that humidity conditions are always suitable for plants in the greenhouse. Based on the test results, the calibration accuracy of the DHT11 temperature and humidity sensor has an average error of 2.73%. While the duration of watering is done by applying Fuzzy logic, the total amount of watering in a day is 2,500 ml of water with a duration of 75 seconds, this is in accordance with the conditions needed in the greenhouse room.

Suggestions for improving this system, further research can be carried out is to add input variables, not only temperature and humidity, but add other variables that also determine the climate in the greenhouse space. Added methods other than fuzzy logic to determine better accuracy.

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