Implementation of Fuzzy Logic Control Method on Chilli Cultivation Technology Based Smart Drip Irrigation System

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ABSTRACT

Herbal chili plants are very beneficial from a health and economic perspective. In the process of cultivating herbal chili plants, there are still many problems that need to be faced, including unfavorable climatic conditions and less intensive cultivation processes. Based on this description, to overcome these problems, technological innovation is needed that can be implemented directly in the cultivation of herbal chili plants. This situation can be achieved by applying a drip irrigation system. This system makes it possible to control the water supply requirements of chili herbs efficiently. System stability can run optimally when combined with a method that can make a decision quickly. Fuzzy logic is used in research because it is able to provide appropriate decisions on temperature and soil moisture data in chili herbs. This research is expected to overcome the problem of water shortages in barren areas. And increase people's interest in the cultivation of herbal chili plants. This research is also an overview and framework for developing the agricultural sector in Madura in the technology field. The results of this study indicate that technology can be designed and integrated with the fuzzy logic control method, then the results of testing the tool also show a 99,98% success rate. This is shown by the results of testing in the morning, afternoon, and evening. The contribution of this study is the control of temperature and humidity which in other studies only focused on the soil, not on the temperature and humidity of the air around the herbal chili plants with a system that has been controlled using the fuzzy method.

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1. INTRODUCTION

One type of plant that has high economic potential is herbal chili. Besides being known as a salt production center, Madura is also popular for its traditional herbal concoctions. Jamu Madura is the result of the intellectual creativity of the Madurese people with formulas and compositions from various plant ingredients that have had special properties in the health sector for generations [1]. One of the benefits of herbal chili is avoiding gastric disorders, toothache, cough, gout, and low blood pressure, and improving blood circulation [1]. One type of material that can be used in making herbal medicine and has been widely cultivated is chili. Jamu chili, or Javanese chili, has the Latin name, Piper Retrofractum Vahl. Piper Retrofractum Vahl is a spice plant native to Indonesia that has many benefits both in terms of health and economy [2]. In the process of cultivating herbal chili plants, there are still many problems that need to be faced, including unfavorable climatic conditions and less intensive cultivation processes. Therefore we need the effort to improve the chili cultivation process using a drip irrigation system automatically using a fuzzy control algorithm. Smart drip irrigation is very suitable for plants that are in the highlands, this system is very suitable and important in maintaining the stability of the water nutritional needs of plants.

The process of growing herbal chili plants requires an adequate level of water availability at the right time of application. This situation can be achieved by applying a drip irrigation system [3]–[30], because this system can adjust the amount and time of water administration according to the needs of the chili plants [8], [15], [17], [31]. The drip irrigation system allows farmers to conserve water use, thereby preventing water loss due to evaporation, runoff, and air [32]. In addition, this system will also save time and money because you don't need to water it excessively, which can even potentially damage the plants. Another advantage of implementing this system is that it produces better crop quality because it has the ability to control moisture around plant roots constantly [33].

The stability of the drip irrigation system can automatically run optimally when combined with a supporting control algorithm. In this study, the authors propose to automatically control the drip irrigation system using a fuzzy control algorithm [17], [21], [22], [34]–[46]. This method is commonly used for control because it is easy to understand and implement in various systems. Fuzzy logic can provide appropriate decisions on temperature and soil moisture data present in plants. The type of fuzzy used is fuzzy Sugeno because this type matches the case study conducted by the author.

Based on the background of these problems, a Smart Drip Irrigation System is needed, which can help facilitate farmers in the process of cultivating herbal chili plants so that the process of cultivating herbal chili plants can be more efficient in the process and the results obtained are more optimal without having to use manual methods. Increasing production and utilizing the amount of water used in plants reduces the occurrence of problems while cultivating red chili plants.

The contribution of this study is the control of temperature and humidity which in other studies only focused on the soil, not on the temperature and humidity of the air around the herbal chili plants with a system that has been controlled using the fuzzy method.

2. METHODS

The research was carried out using experimental methods on the object being tested. The system reading data is in the form of temperature and soil moisture detection by the sensor, which is then translated into input so the system can understand it. Data is processed using a fuzzy logic method algorithm. The flow of research implementation to achieve the stated goals is shown in Fig 1.

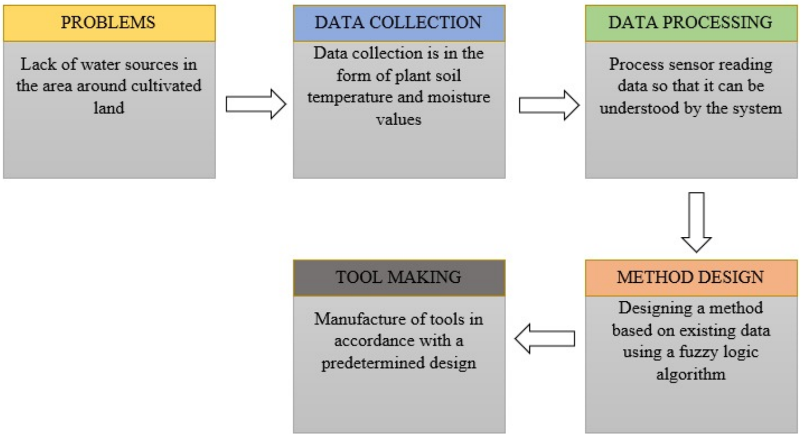


Fig. 1. Research Flowchart

2.1. Electronics System Design

The following is an electronic circuit in the smart drip irrigation system which is shown in Fig. 2. The sensors to be used are soil moisture sensors and DHT 22 sensors [47]. The sensor data will be read and processed by the Arduino microcontroller and then outputs to the relay driver and then forwarded to the water pump to drain water into the hoses connected to the pump. The duration of watering along with the sensor readings in will appear real-time on the LCD. This series can be developed in the form of IoT as research conducted [48]. This research can also use other microcontrollers such as raspberry as done by [49] in his research. The focus of this research is on the accuracy of applying the fuzzy method to the plan. To be able to understand more about the working system of the tool made, see Fig. 3(a) about the system flowchart and Fig. 3(b) about the flowchart of how the method works on this system.

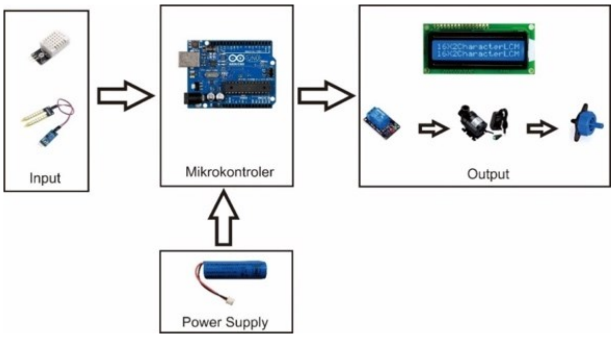
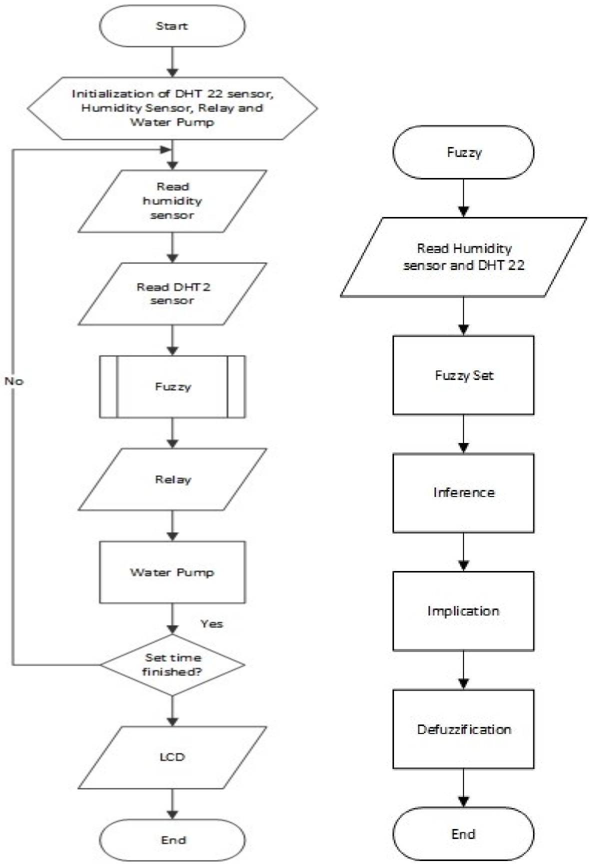


Fig. 2. Electronics design of the Smart Drip Irrigation System



(a) (b)

Fig. 3. Flowchart system (a) Overall System (b) Fuzzy Logic Method

2.2. Application Method

The drip irrigation process runs automatically based on the results of fuzzy calculations. The fuzzy logic uses temperature and soil moisture as variables and returns the watering duration as a result. The electronic system then uses the watering duration to control how long the relay will open the valve to water the plants. This study uses fuzzy Sugeno. In this fuzzy, the rule base creation process is represented as "IF-THEN". The output value is not a fuzzy set but a constant. Then the results of the defuzzification are obtained by finding the average value (weighted average).

2.3. Fuzzy Set Formation

The first stage in the Sugeno fuzzy method is forming a fuzzy set based on variables, which will then be modeled into a membership graph.

a. Soil Moisture Variable

Soil moisture is an input signal ranging from 0 to 100 and is divided into 3 sets (dry, moist, and wet). Table 1. presents the values for the membership function of the soil moisture input. The value range of 0-30% is included in the dry category, the value range of 25-70% is included in the moist category, and the value range of 65-100% is included in the wet category. Refer to Fig. 4.

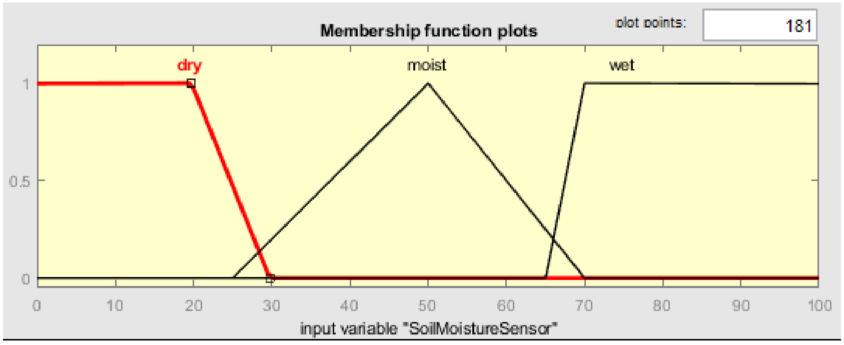


Fig. 4. Degree of Membership of Soil Moisture Variable

b. Variable Temperature

Temperature is an input signal that has a range from 0°C to 40°C which is divided into 4 sets (colder, cold, normal, and hot). Fig. 5. represents the value for the temperature input membership function. The value range of 0°C-22°C is included in the colder category, the value range of 20°C-27°C is included in the cold category, the value range of 25°C-32°C is included in the normal category, and the value more than 30°C° C is included in the hot category.

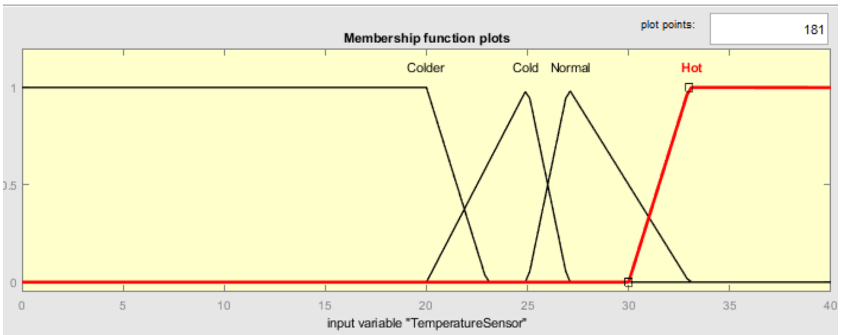


Fig. 5. Degree of Membership Variable Temperature

c. Variable Time (Watering Duration)

Time is an output signal that has a range from 0 to 450 seconds and is divided into 5 sets (very fast, fast, medium, slow, and very slow). Fig. 6 presents the values for the time output membership function. The value of 90 seconds is included in the very fast category, the value of 180 seconds is included in the fast category, the value of 270 seconds is included in the medium category, the value of 360 seconds is included in the slow category, the value of 450 seconds is included in the very slow category. Refer to Fig. 6.

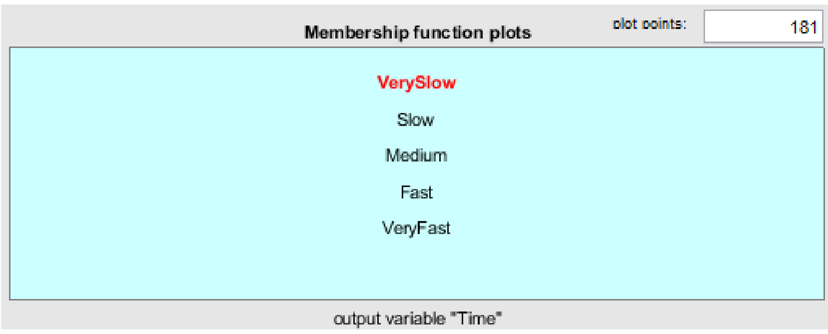


Fig. 6. Degree of Membership Time Variabl

2.4. Inference

A fuzzy Rule is a rule that is made to fulfill the requirements of output occurs. Table 1 is the rule base membership function of soil moisture and temperature as input.

Table 1. Rule Base

		Soil moisture		
	Rule	**Dry (k)**	**Moist (l)**	**Wet (b)**
Temperature	**Cold (d)**	Medium	Fast	Very fast
	Cool (s)	Slow	Medium	Very fast
	Normal (n)	Very Slow	Medium	Fast
	Hot (p)	Very Slow	Medium	Fast

Based on Table 1. Fuzzy's rule base is made, and the rules that will be used in this research can be described. There are 12 rules created, including:
(R1) IF Soil Moisture is Dry AND Temperature is Cold THEN Timer is Medium.
(R2) IF Soil Moisture is Dry AND Temperature is Cool THEN Timer is Slow.
(R3) IF Soil Moisture is Dry AND Temperature is Normal THEN Timer is Very Slow.
(R4) IF Soil Moisture is Dry AND Temperature is Hot THEN Timer is Very Slow.
(R5) IF Soil Moisture is Moist AND Temperature is Cold THEN Timer is Fast.
(R6) IF Soil Moisture is Moist AND Temperature is Cool THEN Timer is Medium.
(R7) IF Soil Moisture is Moist AND Temperature is Normal THEN Timer is Medium.
(R8) IF Soil Moisture is Moist AND Temperature is Hot THEN Timer is Medium.
(R9) IF Soil Moisture is Wet AND Temperature is Cold THEN Timer is Very Fast.
(R10) IF Soil Moisture is Wet AND Temperature is Cool THEN Timer is Very Fast.
(R11) IF Soil Moisture is Wet AND Temperature is Normal THEN Timer is Fast.
(R12) IF Soil Moisture is Wet AND Temperature is Hot THEN Timer is Fast.

3. RESULTS AND DISCUSSION

3.1. System Implementation and How to Operate the Tool

The monitoring system in this study has been designed. The implementation of the results of the tool design has been able to be used as it should, in accordance with the procedure for using the tool. Here's how to operate the tool:

a. Installing sensors on herbal chili plants.
b. Associating the tool with the power source.
c. Turn on the Arduino connection with the internet network.
d. The DHT 22 sensor will measure the temperature and humidity level of the air around the chili herb plants.
e. Soil moisture sensor/soil moisture sensor will measure the level of water content in the soil of the chili herb plant.
f. Arduino will receive data from sensor readings and then send it to the LCD. Fig. 7- Fig. 9 is the final result of the Smart Drip Irrigation System tool for temperature and humidity in cultivating herbal chili plants.

3.2. Overall System Testing

This test is carried out to prove that the fuzzy method works well when experiments are carried out on the system and that the hardware system can operate properly and correctly. In Table 2, the overall results of testing the fuzzy system. The results of the test Table 2 show that the system is running well. The data shows that the percentage of success in calculating the watering time in each trial is 99.98%.

Applying the fuzzy method to the Smart Drip Irrigation System Tool uses the DHT-22 sensor, where the DHT-22 sensor can determine the temperature and humidity in a place or room. Sensor readings are used as input from the fuzzy method used in this study. As for some data collection that has been carried out for 5 days, data collection is divided into 3 parts, namely:

a. Data collection in the morning, 06.00 a.m. - 08.00 a.m.
b. Data collection during the day, 11.00 a.m. - 01.00 p.m.
c. Data collection at night, 06.00 p.m. - 08.00 p.m.

Data collection using the fuzzy method is shown in Table 3. The output of the fuzzy method is PWM to adjust the heater, so that the system response can adjust the output value to the input value given by the DHT-22 sensor.

Table 2. Overall Results of Fuzzy System Testing

Trial to-	Input: Temperature	Input: Soil Moisture	Estimated watering time (seconds)	Time (seconds) from the calculation method results Fuzzy	Percentage of successful calculation of watering time (%)	Solenoid Valves
1	28.16	68.33	444	444.52	99,88	On
2	28.12	68.04	476	476.27	99,94	On
3	29	76.25	240	240	100	On
4	29.12	74.1	240	240	100	On
5	29.16	70.38	240	240	100	On
6	28.64	42.71	480	480	100	On
7	28.55	57.67	480	480	100	On
8	27	66.08	480	480	100	On
9	27.89	55.03	480	480	100	On
10	27.69	65.03	480	480	100	On
The average percentage of successful time calculations sprinkling					99.98	On

Table 3. Testing for Optimization of the Smart Drip Irrigation System tool

Day	Morning			Afternoon			Evening		
	Temp	Soil Moisture	Seconds	Temp	Soil Moisture	Seconds	Temp	Soil Moisture	Seconds
1	28.16	68.33	444	29.11	69.05	480	28.56	68.45	476
2	29.27	76.25	240	30.55	79.65	240	29.21	74.01	240
3	29.21	70.38	240	29.78	70.44	240	28.64	65.83	480
4	28.55	58.56	480	29.23	68.13	480	27.84	66.29	480
5	27.89	55.04	480	28.56	57.61	480	27.45	65.88	480

Fig. 7 is a graph of data collection in the morning on the first day. Data collection was carried out from 06.00 to 08.00. This is done to determine changes in temperature and humidity, as well as the response given by the system.

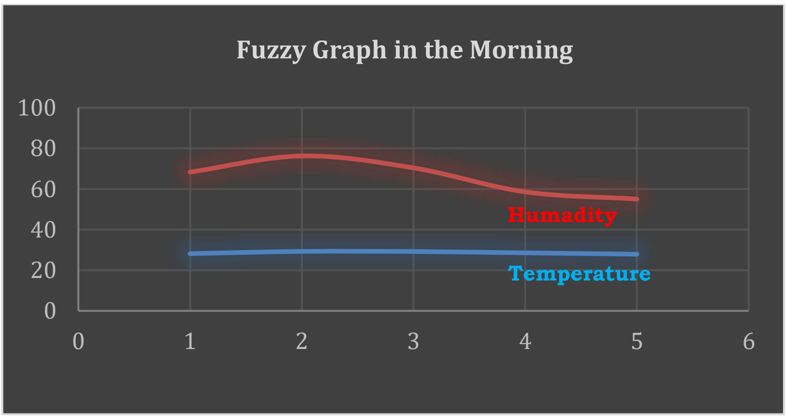


Fig. 7. Fuzzy Graph in The Morning

In Fig. 8, changes in temperature and humidity do not experience much change, only a few changes. Then the temperature and humidity change slightly on days 2 and 3. The emitter used as output can work properly so that the output value can adjust to the input temperature and humidity. Fig. 4 is a graph of data collection during the day.

Fig. 8 shows that there is not much change in temperature and humidity during the day. Data was collected for two hours, from 11.00 to 13.00. This is done to determine the system response for two hours of data collection. This is because the temperature and humidity do not change much. Fig. 5 is data collection carried out at night.

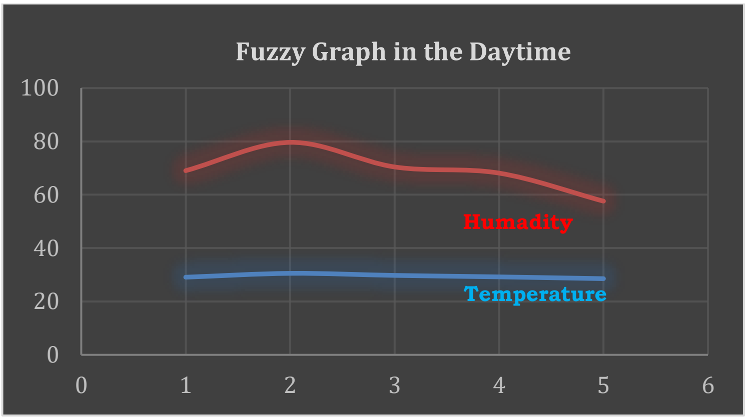


Fig. 8. Fuzzy Graph in The Daytime

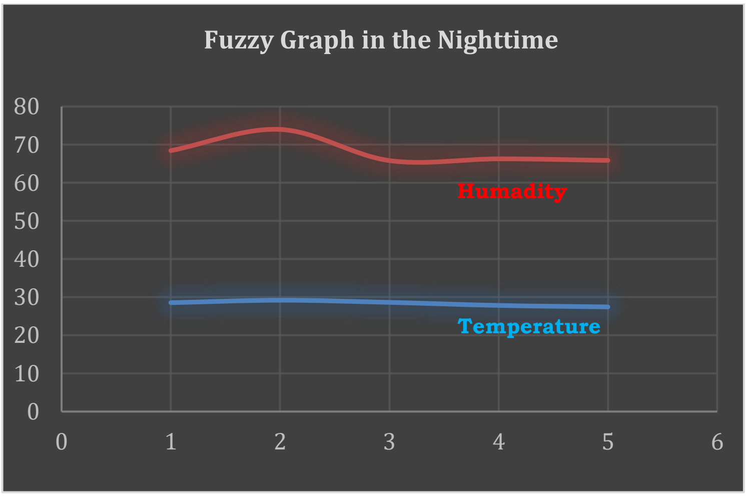


Fig. 9. Nighttime Fuzzy Graph

Based on Fig. 9, changes in temperature and humidity occur from the second day of data collection until the third day. This also affects the output of the dimmer. Changes in temperature and humidity are also affected by changes in humidity outside the Smart Drip Irrigation System. However, the system response works well so that it can adjust the output value based on the input given by the DHT-22 sensor.

From previous research [3]–[30] using the same method and application, it can be compared with previous research that focused on other fields, not chili plants, so the fuzzy method used has a different plan from this study. The success percentage of this research is much better, reaching 99.98%. The limitation in this study is that the system is only capable of being optimal when used in the highlands, this is because the temperature and humidity that can be controlled have very significant growth, but if it is applied to herbal chili plants in the lowlands, the changes are not too significant, resulting in ambiguity in the control process.

4. CONCLUSION

Based on the test results from this study it can be concluded as follow. The system can be designed a smart drip irrigation system for the cultivation of herbal chili plants. The system can be integrated with the fuzzy logic method on the smart drip irrigation system with a success percentage of 99.98%. The system can control the smart drip irrigation system as evidenced by the temperature and humidity at the specified set points.

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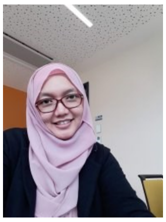

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