Simulation of the Fuzzy Logic Control Method on the Smart Drip Irrigation System for *Piper Retrofractum* Vahl

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ABSTRACT

The growth process of herbal Piper Retrofractum Vahl (cabai jamu) requires a sufficient level of water availability with the right time of administration. This situation can be achieved by applying a drip irrigation system because this system can regulate the amount and time of water supply according to the needs of the plant. The drip irrigation system allows farmers to save water use thereby preventing water loss due to evaporation, runoff, and air. In addition, this system will also save time and cost because there is no need to water excessively which can even potentially damage plants. Another advantage of implementing this system is that it produces better plant quality because it can control the humidity around the plant roots constantly. This system can be applied fuzzy method to obtain optimal results. In this case, it is in the form of a simulation to obtain the level of accuracy of the method if it is applied to the plan. Simulation using Tinkercad which is then assembled according to the plan. The electronic circuit is used to test the accuracy of the fuzzy method on the smart drip irrigation system plan. The results of this study indicate that the electronic system is running well as planned, although there is a change in the type of sensor from DHT22 in the simulation to a TMP36 sensor which basically measures the temperature outside the ground or ambient temperature. The two fuzzy logic control methods that are simulated to be applied to the smart drip irrigation plan are very suitable. This is evidenced by the level of conformity reaching 100% so it can be said that the simulation can be applied directly to the smart drip irrigation system plan.

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1. INTRODUCTION

Spices are types of plants that have aroma and properties. Spices can be used as basic ingredients for herbal and traditional or modern medicines. One of the popular spices developed into herbal medicine and medicine in Madura is Piper Retrofractum Vahl or known as "Cabai Jamu". This type of plant thrives in the highlands with efficacy as a remedy for stomach aches, colds, beriberi, rheumatism, low blood pressure, cholera, influenza, headaches, impotence, bronchitis, and shortness of breath [1].

The growth process of Piper Retrofractum Vahl requires a sufficient level of water availability with the right time of administration [2]. Applying a drip irrigation system can regulate the amount and time of water supply according to the needs of the plant. The drip irrigation system allows farmers to save water use thereby preventing water loss due to evaporation, runoff, and air [2], [3]. This system will also save time and cost because it can avoid watering excessively which can potentially damage plants. Another advantage of implementing this system is that it produces better plant quality because it has the ability to control the humidity around the plant roots constantly.

The drip irrigation system can automatically run using a supportive control algorithm [4]. In this research, the writer examines the accuracy of fuzzy logic to control the system. This method is commonly used for control because it is easy to understand and has been implemented on various systems. In the initial view, fuzzy logic must be able to provide appropriate decisions on temperature and soil moisture data in plants. The type of fuzzy logic used is fuzzy Sugeno. It is hoped that this research on testing the accuracy of the fuzzy method will be used as the basis for the application of the Smart Drip Irrigation System.

2. METHODS

In this study, the simulation of the smart drip irrigation system plan uses Tinkercad web simulation. This simulation allows the application of the fuzzy method to the simulation plan to be built. Based on research conducted by several previous researchers [5]–[34], there are many models and simulations as well as the implementation of the fuzzy method on several plans outside of the implementation of the smart drip irrigation system plan. The method applied is a reference for researchers to design the fuzzy logic control method to be applied to the plan in this study. Referring to some of the previous studies mentioned earlier, in detail the implementation of the application of the fuzzy method in the Design of the Smart Drip Irrigation System is discussed at the point of applying the method in the plan. The design in this study consists of system design, electronics, and methods that will be used by the system, here is the system design that will be made.

2.1. System Planning

Tool system design is a temporary design process of the system to be made. The design of the tool system can make it easier for readers to understand the research that will be carried out by the author, as well as the work system flow of the tool, made [2], [3], [35]. The complete design of the tool system is shown in Fig. 1. The design is still temporary, if there are improvements the system will be changed at a later time.

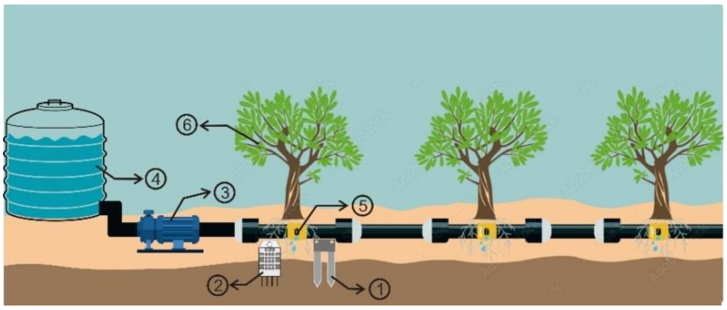


Fig. 1. Smart drip irrigation system design

Description of Fig. 1 is:

1. Soil Moisture Sensor, reads soil moisture or water content around the herbal chili plant.
2. Temperature Sensor (DHT 22), serves to read the temperature around the herbal chili plant.
3. Water Pump, serves to drain water into the hoses connected to the herbal chili plant.
4. Water Tank, is a water reservoir that will be distributed through a hose.
5. Emitter, is a tool that serves to discharge water. The emitter releases water by dripping it directly onto the ground near the plant.
6. Piper Retrofractum Vahl plant, is a plant used in the research case study by the author.

2.2. 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 [36]. 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 [37]. This research can also use other microcontrollers such as raspberry as done by [35] in his research. The focus of this research is on the accuracy of applying the fuzzy method to the plan.

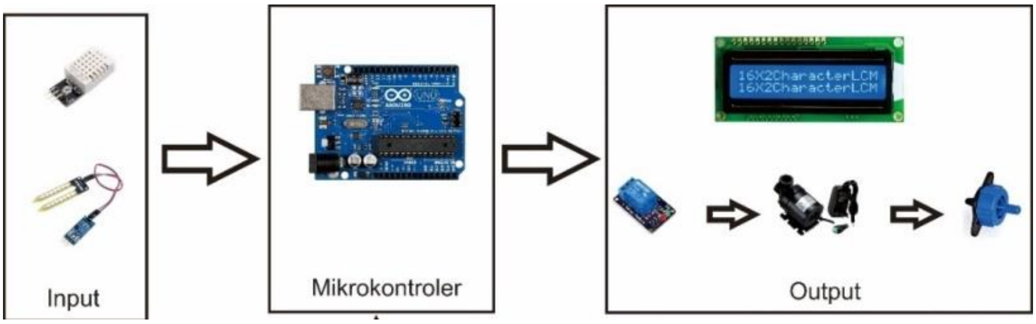
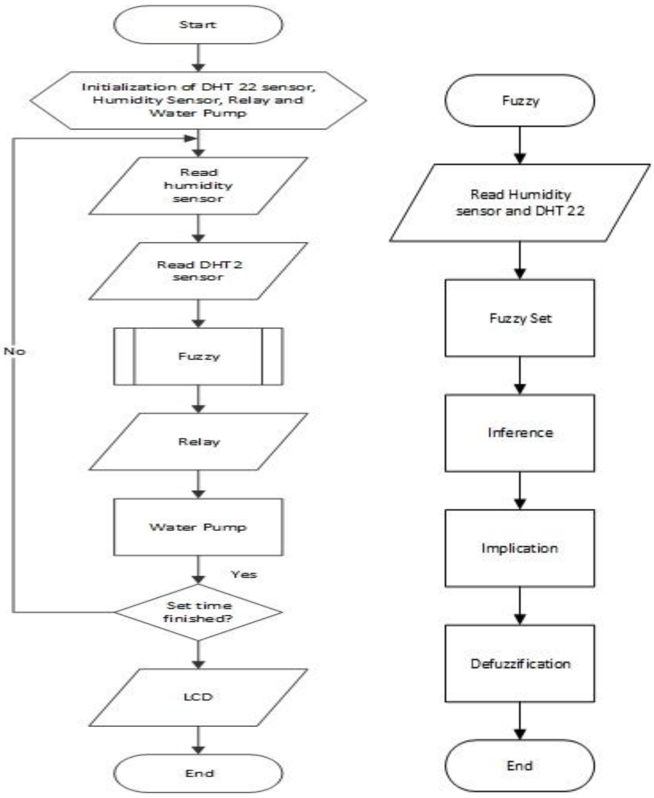


Fig. 2. Electronics design of the smart drip irrigation system

2.3. Work System Flowchart

The overall flowchart of the Smart Drip Irrigation system explains how the system works. First, the sensors and actuators will be initialized. The results of the humidity sensor readings and DHT will be processed by the fuzzy method to be able to provide an output decision on how long to water plants. 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.



(a) (b)

Fig. 3. Flowchart system (a) Overall system (b) Fuzzy logic method

2.4. 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 the 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 type of fuzzy, rule base creation process is represented in the form of

"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).

2.4.1. Fuzzy Set Formation

The first stage in the Sugeno fuzzy method is the formation of 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 that has a range from 0 to 100 and is divided into 3 sets (dry, moist, and wet). Fig. 4 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.

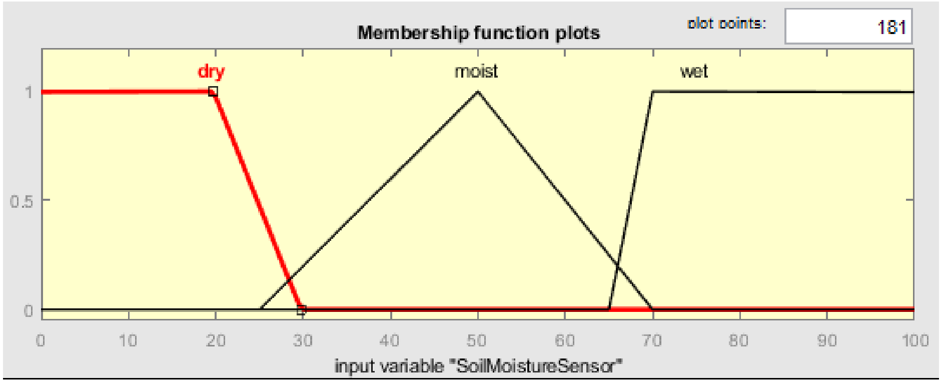


Fig. 4. Degree of membership of soil moisture variable

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.

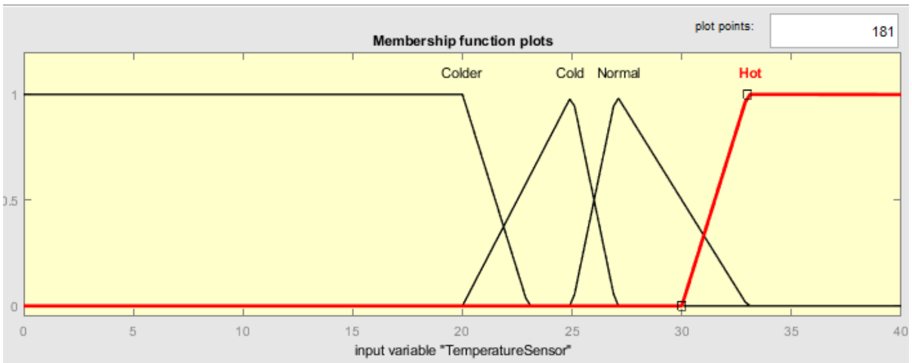


Fig. 5. Degree of membership variable temperature

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.

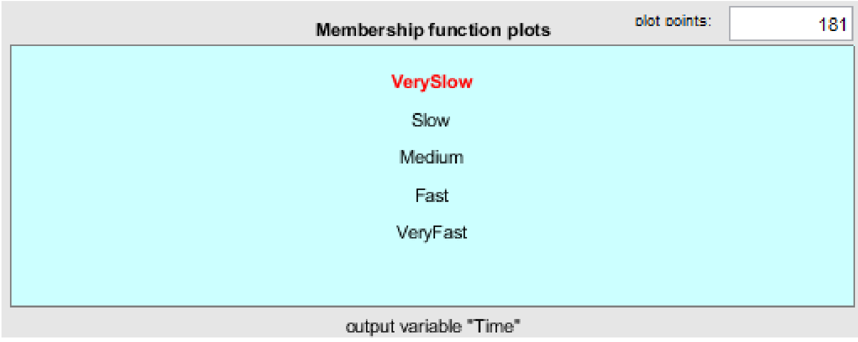


Fig. 6. Degree of membership time variable

2.4.2. 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

This study uses tingkercad to test methods and plans in the form of simulations. The plan begins with the design of electronic simulation components, then continues with the implementation of the program in the simulation plan.

3.1. System Installation

The initial design is carried out to determine the components needed to perform simulations on the system. The components that have been designed will be used to obtain the accuracy value of the fuzzy logic control method on the smart drip irrigation system plan. Components as shown in Table 2 are required for the simulation.

Table 2. Components of the simulation plan

Component	**Total**
Arduino Uno Version R3	1
Soil Moisture	1
Temperature Sensor TMP36	1
LCD 16x2 I2C	1

The components in Table 1 are then assembled using the Tinkercad web app. Assembling between components using jumper cables, in the form of simulations using lines that are connected according to component pins. The component installation is declared complete if there are no errors in the whole system. Fig. 7 shows the circuit of simulation components. Fig. 8 shows the schematic of the circuit.

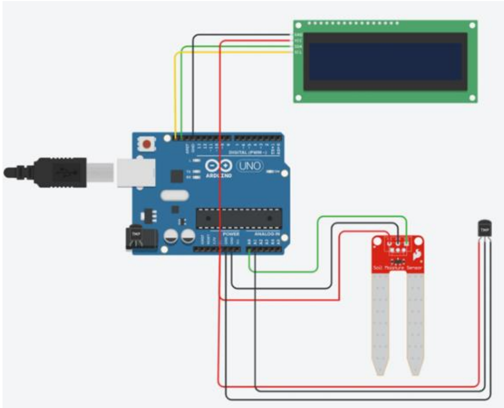


Fig. 7. System simulation series

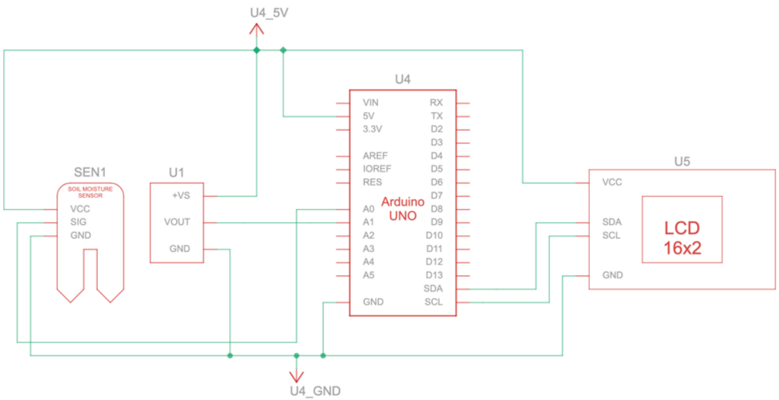


Fig. 8. Schematic electronic system

3.2. Testing the Simulation

Testing the simulation consists of two stages. The first stage is testing the temperature and humidity sensors on the electronic circuit simulation. The second stage is testing the integration of the system as a whole (electronic circuit simulation which is implanted with the fuzzy logic).

3.2.1. Testing Electronic Circuit Simulation

In this test, the temperature sensor is set to 24.7°C while the humidity sensor is set to 55%. The result is shown in Fig. 9.

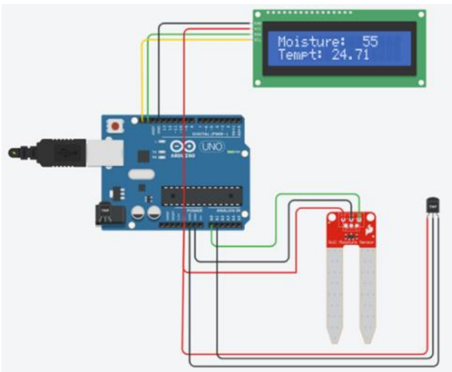


Fig. 9. Simulation testing of temperature and soil moisture sensors

The display of sensor readings indicates that the integrated electronic system is running well. It should be noted that the temperature sensor outside the ground that should have used DHT22 in this simulation was replaced by the TMP36 temperature sensor. This condition is due to the limitations of the sensor library in the Tinkercad application.

3.2.2. Testing the Fuzzy Logic in The Simulation

Testing the fuzzy logic on the system begins with uploading the program to the microcontroller in the electronic circuit simulation. Some input parameters are defined to test whether the logic gives the expected results. Table 3 shows the results of the simulation test along with the defined input parameters.

Table 3. Test results of the method on the plan

No	Temperature Sensor (˚C)	Soil Moisture Sensor (%)	Output on simulation	Accuracy (Appropriate/Not Appropriate)
1	20.6	21	Medium	Appropriate
2	22.6	32	Fast	Appropriate
3	24.5	51	Medium	Appropriate
4	27.4	65	Medium	Appropriate
5	29.9	69	Fast	Appropriate
6	34	76	Fast	Appropriate
7	35.7	78	Fast	Appropriate
8	27	15	Very Slow	Appropriate
9	26	10	Slow	Appropriate
10	38	80	Fast	Appropriate

Table 3 also shows ten simulations that are giving appropriate results. The simulation drawing of the application of the fuzzy logic on the plan is shown in Fig. 10.

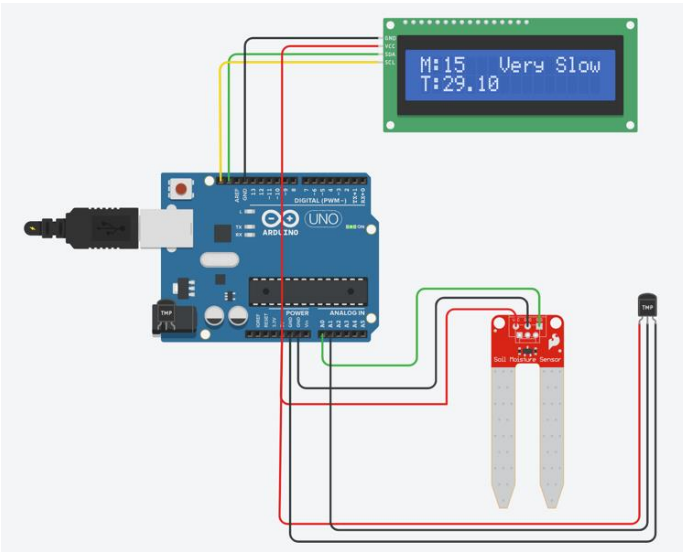


Fig. 10. System testing using the fuzzy logic control method

The uniqueness of the results of this study answers several problems in previous research conducted by [12], [13], [16], [19]–[21], [24], [25], [27], [31], [36] with the subject of modeling and simulation of logic control methods in the plan. The results of the simulation show an accuracy rate of 100%, meaning that the simulation runs well and can be applied to the Smart Drip Irrigation System Piper Retrofractum Vahl plan directly.

4. CONCLUSION

From the results of this study, it can be concluded that the electronic system is running well as planned, even though there is a change in the sensor device in the simulation which is basically the same function. The fuzzy logic control methods that are simulated to be applied to the smart drip irrigation plan are very suitable.

This is evidenced by the level of conformity reaching 100% so it can be said that the simulation can be applied directly to the smart drip irrigation system plan.

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