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Automatic Plant Watering System Based on Air Temperature and Soil Humidity Using the Fuzzy Sugeno Method

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Abstract: Plants need water to grow well, so watering must follow the plant's needs. Parameters that affect the process of watering plants are air temperature and soil moisture, thus, we need a control system that can make decisions in the form of watering time to meet plant water needs according to their needs, namely an automatic watering system. Fuzzy method can be used for human-like decision making in a control system. This study uses the Sugeno fuzzy method which is integrated into the Microcontroller as the controller. Testing of this system is carried out on eggplant plants which are regulated based on how long the watering time is so that the air temperature and soil moisture are following the plant's needs. The test resulted that the effective watering time interval so that the eggplant soil moisture was maintained at 40-60% was 21 seconds. It can be concluded that the fuzzy inference embedded in the design has been able to overcome the problem of watering eggplant plants, where the test shows that after the watering process, the soil moisture value can be maintained at an average value of 55% so that the soil moisture is following the needs of the plant.

Keywords: Air Temperature ; Automatic Watering ; Eggplant ; Fuzzy Sugeno ; Microcontroller ; Soil Moisture

INTRODUCTION

Watering is the most important routine for plant growth and development. Not only the amount of water discharge, but the length of watering also needs to be considered to suit the needs of the plant. The amount of water may be very large if watering the plants for too long, the amount of water is not enough because the watering time is not long enough (Sanca, 2018). Watering plants that are only based on schedule will certainly not be effective in uncertain weather conditions. The automatic watering system is designed to help make it easier to provide water when plants need it. Plants have their requirements for life. One of them is eggplant which can grow optimally in a humidity range of 40%-60%, thus a system is needed to determine how long eggplant plants are watered to keep soil moisture in its optimal range. From the timing problem in watering plants above, it is necessary to have a special control system, a tool that can carry out watering activities automatically (Ariyanto & Kusriyanto, 2020).

Along with the development of technology, especially in the field of electronics, which can help handle human work. The electronic circuit that acts as a control or control system is a Microcontroller. The method by which fuzzy logic can be done in the controller is one of the methods by which the control system can make similar inferences to the decisions made by humans because its concept is based on natural language so quite easy to understand (Mursalin et al., 2020).

Research has been conducted by Ayu Ardyanti on "Automatic Watering Plants with the Fuzzy Mamdani Method" in 2021, in this study the design of an automatic watering system with fuzzy Mamdani was applied to the Microcontroller as a reference on making decisions whether plants will be watered or not, the data is taken from the value of the soil moisture sensor and air temperature sensor, the goal is that the water can be watered according to its needs (Ardyanti, 2021).

This study uses the implementation of Fuzzy Sugeno logic on an integrated control system on the Arduino Uno Mikrocontroller with input parameters of air temperature and soil moisture to get the length of watering time according to the needs of eggplant plants. Sufficient water needs can help increase agricultural yields.

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LITERATURE REVIEW

Soil is the environment, where plants grow with certain characteristics, due to the combined influence of material factors, sources, climate, living organisms, or the shape of the area and the time of excavation. Soil can be defined by the breakdown of mineral particles with little or no grains, which are formed by weathering of rocks. (Rachman, 2018). Soil with good structure can encourage the activity of good plant growth factors, while soil with poor structure can inhibit plant growth. Soil structure is good if there is a good spatial distribution of pore space, in other words, there is space for pores in spaces filled with water and air. (Tullah et al, 2019)

The level of soil moisture is very influential on plant life in the soil. Plants always need to depend on the period of vegetation, because that's when new plants are formed and the plants themselves contain a lot of water, not seeds. Dry soil moisture of 0% is assumed when dry soil conditions have no water content in the soil even though there is groundwater content in the field. Furthermore, when the soil condition is 100% saturated, it is assumed that soil conditions have layers and soil pores that have been filled with water content even though there are a few air voids in the soil pores, especially in the base layer of the soil (Yudhisthira et al., 2018). Temperature is how hot or cold, is measured against a certain scale, Air and soil temperatures affect plant growth. Each type of plant has a different minimum, optimal, and maximum temperature limit for each growth rate (Noorhadi, 2018).

Watering/irrigating plants aims to meet the water needs of plants and treat excess/unused water as excess/drainage. Therefore, with this system, water supply and treatment can be controlled both in quantity and time. Plants can be watered by watering the entire plant thoroughly so as not to damage the plant; use a spray/flush hose so that the water that splashes onto the plants can be in the form of fine particles. An automatic watering system is a system consisting of installed equipment. For automatic garden watering, the system can be able to turn the pump on and off automatically over time, adjusting to the amount of water. Then, both can also be integrated with several other smart features (Suwarsi, PU, and Sumali, 2018). Automation can be realized by using a Microcontroller control system. The Microcontroller is a technological breakthrough in microprocessors and microcomputers. It is a semiconductor technology that contains more transistors but takes up less space (Alam et al., 2020).

METHOD

In this study, Fuzzy Sugeno logic is used to determine whether eggplant plants need to be watered based on the value of air temperature and soil moisture, if the value is not sufficient for the plant's needs, the system will determine the length of watering until the value is sufficient. The value is taken based on the data on the conditions of plant growth. Data collection was carried out in two ways, the first step was direct observation at the Department of Agriculture and Marine Affairs of Medan City, to obtain information about plant life requirements and watering procedures. The second step is a literature study by observing various literature in the form of books, journals, and others about eggplant plant life requirements for automatic watering of plants, as well as components that can be used.

Referring to the opinion of Takagi-Sugeno Kang, Sugeno's fuzzy method is a fuzzy inference method of rules expressed in IF-THEN form, where the results (consequences) of the system are not fuzzy sets, but constants or linear equations. There are 4 stages/steps to get the results, there are form fuzzy sets, applying implicit functions, rule composition, and Defuzzification (Romney & Steinbart, 2018).

Planning

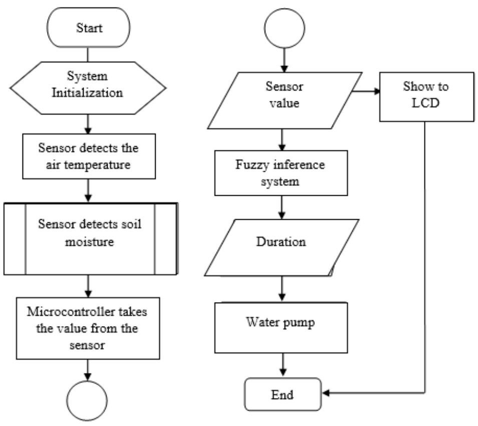

Fig 1. *Flowchart* System

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In this study, researchers plan how the system will be built using a flowchart. The description and explanation of the flow of the program in detail are as follows:

This stage, the production process of system hardware is applied where first a block diagram is made which will describe the input, process, and output components of the system as follows :

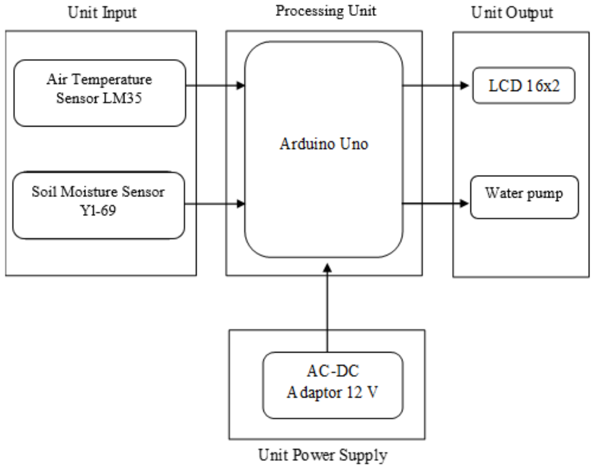

Fig 2. Hardware Building Block Diagram

Design
The design of this hardware is in the form of an electronic system design of the entire system components.

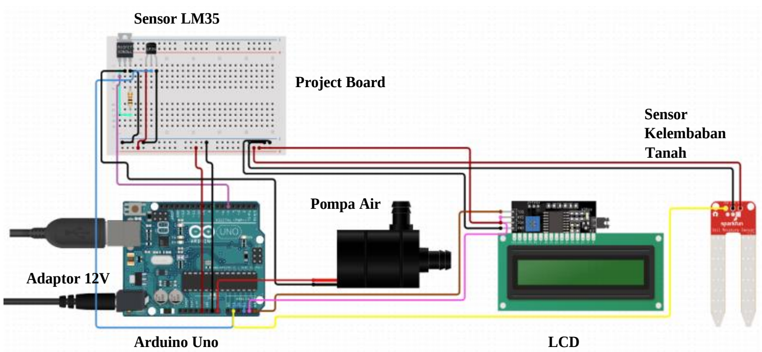

Figure 3. Circuit Electronics System

There are a few input and output components in the system that are connected to the Arduino Uno.

Table 1 . Configuration Series

No	Component	Pin	Arduino Pins
1	Soil Moisture Sensor	Data	A0
		Vcc	5V
		Gnd	Gnd
2	Air Temperature Sensor	Data	A1
		Gnd	Gnd
3	16*2 . LCD	Vcc	5V
		Gnd	Gnd
		natural resources	A4
		SCL	A5
4	Water Pump	Gnd	Gnd
		Vcc	5V
		RX	8
		TX	9

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RESULT

The parameters obtained from the results of data collection which are then used This system uses soil moisture and air temperature. The values of air, temperature and soil moisture are used as variables in determining how long to water.

Fuzzifications

There are two membership functions used in this study, namely the sensor input membership, function, and the water pump output membership function.

Table 2. Fuzzy Set

Function	Variable	Fuzzy Set	Domain
Input	Air Temperature	Cold	[0, 15, 21, 23]
		Normal	[21,23, 27, 31]
		Heat	[27, 31, 32, 35]
	Soil Moisture	Dry	[0, 0, 35, 40]
		Humid	[35, 40, 65, 80]
		Wet	[77, 90, 100, 100]
Output	Water Pump	Off	[0]
		Fast	[0.7]
		Slow	[7.21]

The air temperature membership function consists of three fuzzy sets, namely cold, normal, and heat.

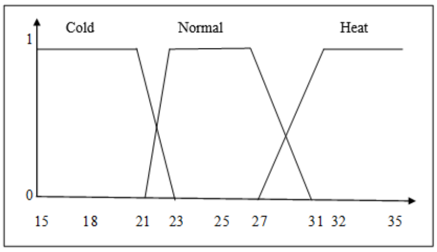

Fig 4. Air Temperature Set

Based on the graph of the membership function of the air temperature set, a membership degree formula can be made as follows:

$$\mu Cold \begin{cases} 1; & x \leq 21 \\ \dfrac{23-x}{23-21}; & 21 \leq x \leq 23 \\ 0; & x \geq 23 \end{cases}$$

$$\mu Normal \begin{cases} 0; & x \leq 21 \; atau \; x \geq 31 \\ \dfrac{x-21}{23-21}; & 21 \leq x \leq 23 \\ 1; & 23 \leq x \leq 27 \\ \dfrac{31-x}{31-27}; & 27 \leq x \leq 31 \end{cases}$$

$$\mu Heat \begin{cases} 0; & x \leq 31 \\ \dfrac{x-31}{35-31}; & 31 \leq x \leq 35 \\ 1; & x \geq 35 \end{cases}$$

Soil moisture membership function consists of three fuzzy sets, namely dry, humid and wet.

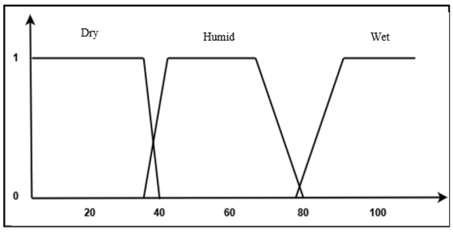

Fig 5. Set Soil Moisture

The membership degree formula is as follows :

$$\mu Dry \begin{cases} 1; & x \leq 35 \\ \dfrac{40-x}{40-35}; & 35 \leq x \leq 40 \\ 0; & x \geq 40 \end{cases}$$

$$\mu Humid \begin{cases} 0; & x \leq 35 \; atau \; x \geq 80 \\ \dfrac{x-35}{40-35}; & 35 \leq x \leq 40 \\ 1; & 40 \leq x \leq 65 \\ \dfrac{80-x}{80-65}; & 65 \leq x \leq 80 \end{cases}$$

$$\mu Wet \begin{cases} 0; & x \leq 77 \\ \dfrac{x-90}{90-77}; & 77 \leq x \leq 90 \\ 1; & x \geq 90 \end{cases}$$

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The air temperature value is 30°C and the soil moisture value is 40%. By using the function above, to get the Fuzzifications value by :

Membership Function Air Temperature 30°C

$$\mu Cold[30] = \frac{31-x}{31-27} = \frac{31-30}{31-27} = \frac{1}{4}$$
$$= 0{,}25$$

μHeat [30] = 0

$$\mu Normal[30] = \frac{30-21}{23-21} = \frac{30-21}{23-21} = \frac{9}{2}$$
$$= 4{,}5$$

Membership Function Soil Moisture 40%

μDry [40] = 0

μWet [30] = 0

$$\mu Humid[40] = \frac{80-x}{80-65} = \frac{80-76}{80-65} = \frac{5}{15}$$
$$= 0{,}26$$

Evaluation and Composition Rules

The rule is formed as a statement of the relationship between input (input) and output (output).

[1st rule] If (humidity is Dry) and (temperature is Cold) then (Water pump is Fast)

$$\alpha - predicate\ 1 = \mu Dry\ \cap\ \mu Cold$$
$$= min(\mu Dry[35], \mu Cold[30])$$
$$= min(0; 0{,}25)$$
$$= 0$$

[2nd rule] If (humidity is Dry) and (temperature is Normal) then (Water pump is Fast)

$$\alpha - predicate\ 2 = \mu Dry\ \cap\ \mu Normal$$
$$= min(\mu Dry[35], Normal[30])$$
$$= min(0; 4{,}5)$$
$$= 0$$

[3rd rule] If (humidity is Dry) and (temperature is Heat) then (Water pump is Slow)

$$\alpha - predicate\ 3 = \mu Dry\ \cap\ \mu Heat$$
$$= min(\mu Dry[40], \mu Heat[30])$$
$$= min(0; 0)$$
$$= 0$$

[4th rule] If (humidity is Humid) and (temperature is Cold) then (Water pump is Off)

$$\alpha - predicate\ 4 = \mu Humid \cap\ \mu Cold$$
$$= min(\mu Humid[40], \mu Cold[30])$$
$$= min(0{,}26; 0{,}25)$$
$$= 0{,}25$$

[5th rule] If (humidity is Humid) and (temperature is Normal) then (Water pump is Off)

$$\alpha - predicate\ 5 = \mu Humid \cap\ \mu Normal$$
$$= min(\mu Humid[40], \mu Normal[30])$$
$$= min(0{,}26; 4{,}5)$$
$$= 0{,}26$$

[6th rule] If (humidity is Humid) and (temperature is Hot) then (Water pump is Off)

$$\alpha - predicate\ 6 = \mu Humid \cap\ \mu Heat$$
$$= min(\mu Humid[40], \mu Heat[30])$$
$$= min(0{,}26; 0)$$
$$= 0$$

[7th rule] If (humidity is Wet) and (temperature is Cold) then (Water pump is Off)

$$\alpha - predicate\ 7 = \mu Wet \cap\ \mu Cold$$
$$= min(\mu Wet[40], \mu Cold[30])$$
$$= min(0; 0{,}25) = 0$$

[8th rule] If (humidity is Wet) and (temperature is Normal) then (Water pump is Off)

$$\alpha - predicate\ 8 = \mu Wet\ \cap\ \mu Normal$$
$$= min(\mu Wet[40], \mu Normal[30])$$
$$= min(0; 4{,}5)$$

* name of corresponding author

$= 0$

[9th rule] If (humidity is Wet) and (temperature is Heat) then (Water pump is Off)

$$\begin{aligned} \alpha - predicate\ 9 &= \mu Wet\ \cap\ \mu Heat \\ &= min(\mu Wet[40], Heat[30]) \\ &= min(0; 0) \\ &= 0 \end{aligned}$$

Defuzzification

There are 3 linguistic values chosen to represent the condition of watering time :

Fig 6. Water Pump Set

After carrying out the process of analyzing the Sugeno fuzzy data above, then the system testing is carried out. The hardware is integrated into the Arduino board and other components that have been described previously, using several electronic components such as Arduino Uno, air temperature sensor, soil moisture sensor, water pump, LCD, and power supply. All input and output data is processed on the Arduino board, thus the Arduino board functions as the main component of the system. The following figure shows a system hardware circuit consisting of components that have been combined.

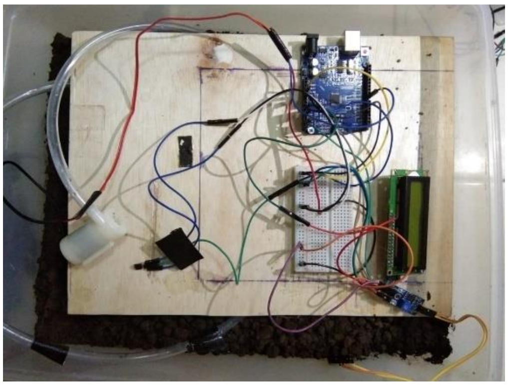

Fig 7. Hardware Circuit

Testing of automatic plant watering equipment is carried out by preparing soil samples along with eggplant plants where the sensor readings are displayed on the LCD, as shown below :

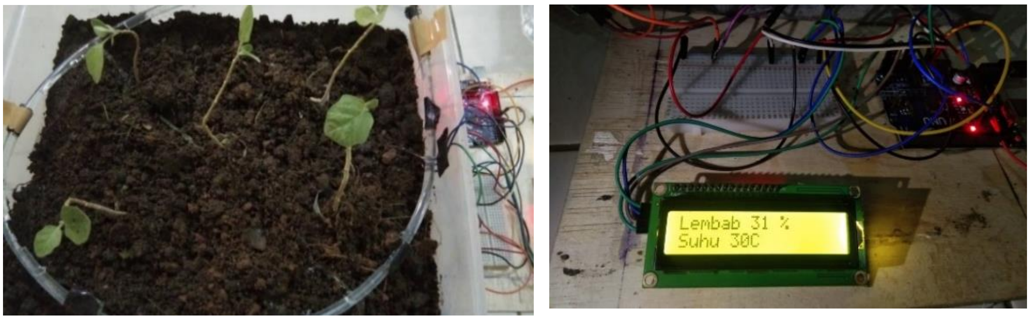

Fig 8. Eggplant Plant Watering Test

The success rate in this testing is the watering time according to the output produced by the fuzzy system, namely dry soil moisture and hot temperature, the length of watering is 21 seconds.

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Table 3. Fuzzy System Program Testing

No	Input		Watering Time Output System (seconds)	Manual Calculation
	Temperature	Humidity		
1	28°C	32%	Slow 21 (sec)	Slow 21 (sec)
2	30°C	31%	Slow 21 (sec)	Slow 21 (sec)
3.	33°C	42%	Off 0 (sec)	Off 0 (sec)
4.	31°C	37%	Slow21 (sec)	Slow 21 (sec)
5.	29°C	63%	Off 0 (sec)	Off 0 (sec)

Table 4. System Testing on Eggplant Plants

Test	O'clock	Sensor Reading		Watering Time (seconds)	Soil After Watering (%)
		Temperature (°C)	Humidity		
Day 1	08:00	28°C	32%	21 (sec)	49%
	17:00	30°C	31%	21 (sec)	59%
	Average after watering				54%
Day 2	08:00	29°C	63%	0 (sec)	63%
	17:00	33°C	50%	0 (sec)	50%
	Average after watering				56%
	Average after 2 days of testing				55%

Based on the 2-day test data, this system can maintain soil moisture following the conditions desired by the eggplant plant. The total average soil moisture after watering for 2 days of testing was 55%.

DISCUSSION

This study resulted in an automatic watering system for plants based on air temperature and soil moisture as an effort to contribute to routine plant watering activities that are still carried out manually. The method used in designing this system is the Fuzzy Sugeno method with 2 inputs, namely air temperature, and soil moisture, and output is the length of time for watering from the water pump.

After the system is successfully designed then the system performance is tested. The test is carried out by plugging 2 sensors into the ground on eggplant plants. The test results are 1. Based on the results of the system testing on eggplant plants, the average air temperature per day is 30°C and the average soil moisture per day is 31%, the effective watering time for each watering is 21 seconds. Thus the system is designed to run well following the implementation of the Fuzzy Sugeno method in the system. Researchers hope that the system that has been built can be further developed to be better and more useful for future researchers.

CONCLUSION

After implementation and testing on the system, then the result is that the fuzzy inference system for watering plants can be said to have been able to overcome the problem of watering plants, especially eggplant (ideal soil moisture conditions 40%-60%). From the system testing conducted for 2 days for 1 container containing eggplant plants, the average value of soil moisture for 2 days of testing can be maintained at 55%, according to plant needs. Testing of each component has shown that the automatic control of the watering system has been running according to the program equipped with LCD as an information display, a YL-69 type soil moisture sensor as a soil moisture detector, and an LM35 sensor to detect air temperature.

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