Fuzzy logic Flow Control for Drip Irrigation with GUI

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***Abstract*— A huge part of water, which is 60%, used in irrigation is wasted due to over and under watering in agriculture industries. Irrigation is one of the necessities when growing a plant. Automated Irrigation is the best way to reduce manpower and water in Agriculture. This was possible by using temperature and soil moisture sensor. The fuzzy algorithm will analyze the measured parameters from the sensors then the system will supply an exact amount of water to the plants which depends on the fuzzy output. The measured parameters will be displayed using Graphical User Interface (GUI) for monitoring purposes. Based on the results, the measured and actual data were almost same. As a conclusion, the automated system is more efficient than the traditional way of irrigating the plants.**

***Index Terms*— fuzzy, irrigation, flow control system, gui, drip irrigation**

I. INTRODUCTION

Irrigation has a big role in agricultural industry. Water is supplied to the crops for agricultural production, this method is called irrigation. Proper irrigation leads to a higher quality of crops. It also helps the plants to withstand seasonal variability and drought [1].

Ditch, terraced, sprinkler, center pivot and drip irrigation are the types of irrigation. Digging out the ditches and planting seedlings in a row is ditch irrigation. Conservation of irrigation wherein the land is cut into steps and growing of crops is put in the flat surface [2]. While distributing water using high pressured sprinklers from the center of the field is called sprinkler system. And a sprinkler system moving in a circular motion on wheeled towers is called center pivot irrigation [3]. The method which drips the water straight to the root zone of the crop is called drip irrigation [2]. Although traditional methods are cheaper, they are not water efficient as the modern or advanced methods [4].

In this modern day, more and more methods are being developed to conserve water by automating the irrigation of the crops. This automated irrigation used different techniques to control the irrigation system. Controlling and monitoring the irrigation process can be done by the used of Internet of Things [5] [6] [7]. ANFIS (adaptive-network-based fuzzy inference system) can implement neural networks together with principles of fuzzy logic. The rule base selection in ANFIS is more adaptive or suitable to the condition [8] [9] [10]. The Fuzzy logic which seems like a human reasoning, is basing on the levels of possibilities of input to achieve an accurate or a definite output [11] [12] [13].

However, said techniques also have disadvantages. The IoT system uses an android application to monitor and control irrigation, and to display the gathered data, this kind of system would not be a farmer friendly [5]. ANFIS algorithm has limitations which involves large inputs such as dimensionality curse and expense computations which causes the application to stop [14]. While in Fuzzy Logic Algorithm, tuning carefully is needed in order to achieve its maximum performance [15].

This study develops a smart irrigation system, which is drip irrigation with the use of fuzzy logic algorithm. The input of the system will be the sensors, specifically moisture of the soil and room temperature sensors. Value of soil moisture and temperature measured by the sensors are needed as input to the fuzzy. The amount of needed water to be distributed to the crops will be the output which is volume-based.

II. RELATED STUDIES

Numerous studies about the automation of irrigation system were conducted and implemented to control the flow of irrigation using different methods. One of these studies by Paucar, et al., used a decision support to automate the irrigation by the used of wireless distributed sensors. The objective of the study is to develop a system for smart watering which will evaluate the duration of needed irrigation. The input parameters of the system are temperature and humidity values in order to obtain the irrigation time. However, the system developed has a time-based output wherein the pressure of irrigation is not constant [1].

Another study about automation of irrigation system by Devika, et al., used Arduino and soil moisture sensor to automatically sense the soil moisture and to decide the time and the volume of water to be distributed. The system relies on the moisture of the soil, if the moisture content that is measured by the sensor is lower than the limit, the system will start irrigating the plants with the required amount of water. This system might have inaccurate data since it used only one parameter which is moisture content of soil [2].

A study by Anand, et al., used fuzzy logic to optimize the used of water and fertilizer. Their study used sensors to collect data such as temperature and humidity. It also used a communication link to monitor, control and schedule the system through cellular text messages. The study can be concluded to be effective in deciding of how long and how much water will be used. However, this system is a time-based

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output also, the moisture content of the soil was not considered for input parameters [3].

A Graphical User Interface (GUI) makes it easy to interact with a device or a system so it is important to have a well-designed GUI, several studies were conducted about Irrigation system with a Graphical User Interface. Usmonov and Gregoretti designed a GUI app using Kivy, a python framework for GUI application for controlling drip irrigation. Their GUI app was implemented on Linux and Windows wherein the user can edit, add information or remove solenoid valves. However, collected data were not included in the app, it can only monitor and control the activities of solenoid valves and pump [4].

Another study was developed by Ishak, et al., wherein Irrigation system is developed with Graphical User Interface (GUI) with the used of Android application in smartphone to monitor and control the watering activity. It can also monitor the parameters which are light and moisture level of the test field. As a result, with a GUI, the user can successfully control and observe the irrigation system remotely [5].

III. METHODOLOGY

A. Hardware Development

The general block diagram of the system is displayed in the Figure 1 The soil moisture and room temperature are the parameters used. These will be measured by the sensors in each plant bed. Then those parameters will be the input to the Fuzzy logic control system. Output data for fuzzy will be the volume of water needed by the crops. Then the valve will open and closes when the output volume as indicated by the fuzzy is reached. The measured parameters which are soil moisture, temperature, and volume of water will be displayed in an LCD.

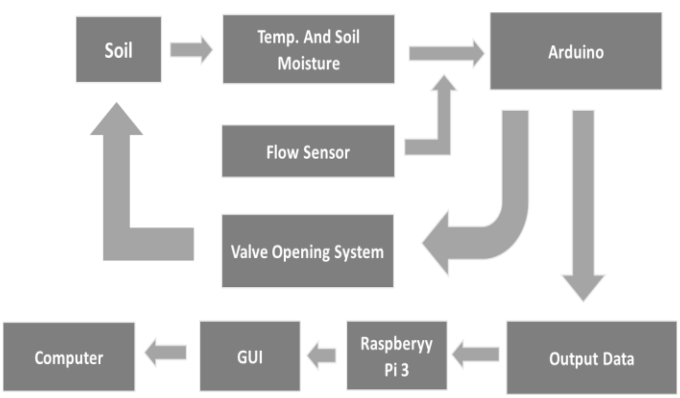

Fig 1. General Block Diagram of the system

Figure 2 displays general block diagram of the whole drip irrigation system. The values which are measured from the sensors are the input and the limiter of the volume will be the measured value from the flow sensor. Valves are open unless it reached the amount of water or the output volume. A separate 12V power supply will be the power source of the relay module.

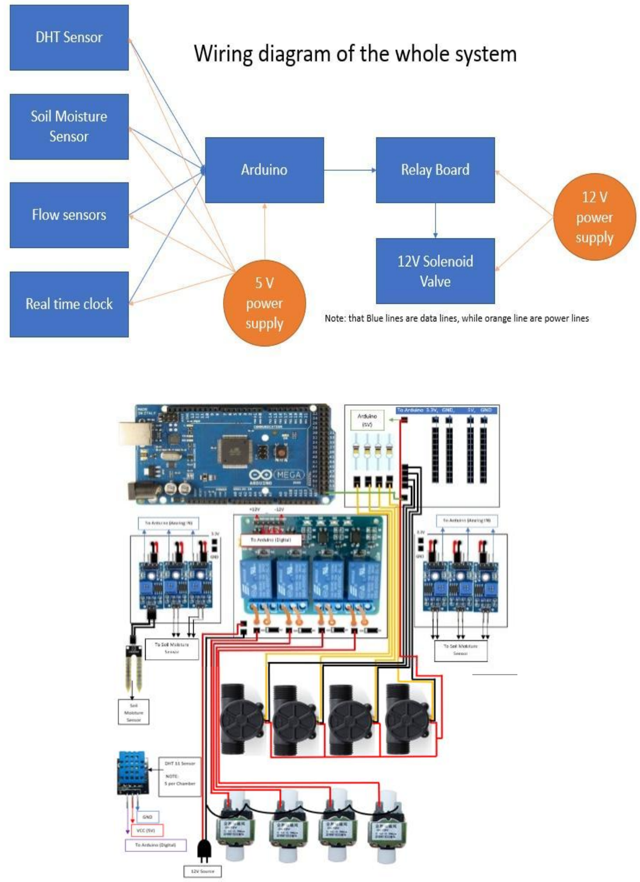

Fig 2. Wiring Diagram and Circuit of the Whole System

B. Fuzzy Logic Algorithm

Figure 3 shows the controller of fuzzy logic. The logic which works close to human brain is the fuzzy logic algorithm where there is "degrees of membership" rather than the traditional Boolean logic [18]. It is an algorithm which is close to how brain of a human thinks or functioning. The computed mean of moisture and temperature is used for the Fuzzification to determine the amount of irrigation needed which is the fuzzy output

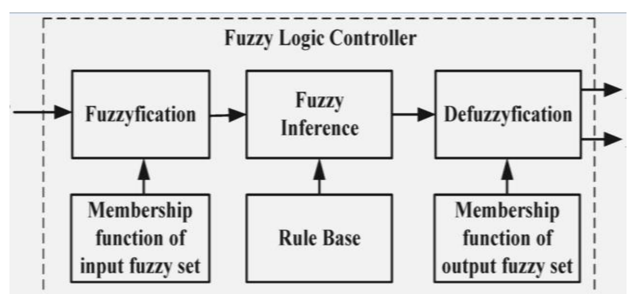

Fig.3 Fuzzy Logic Controller

Figure 4 shows the fuzzy logic of the system. The average temperature and average soil moisture are the input parameters to the fuzzy and at the output section is the amount of irrigation daily.

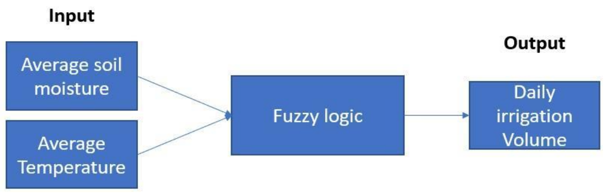

Fig.4 Fuzzy Logic System

C. Fuzzification

Fuzzy value can be obtained by the process called Fuzzification, in which the crisp data will be changed into fuzzy value. Fuzzification can be achieved through Fuzzifiers. Trapezoidal and triangular are used in this study. Some cases of a trapezoidal function are used in the input membership functions where the R-function and L-function. It is Right function if limits a and b are equal, and Left function if limits c and d are equal. When limits b and c is equal, the triangle can be treated as trapezoid.

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C.1 Input Membership function

Figure 5 shows the membership function for moisture of the soil. It is divided into 3 degrees of membership. The membership degrees are represented by Fuzzy linguistic Variables: Dry, Moist, Wet. A suitable membership function must be used for the soil moisture, this will be a membership function that is trapezoid-shape because it has an advantage in simplicity and it also has a wide range of values. The fuzzy input of fuzzy inference will be the average soil moisture. Degrees of membership for each is (0, 0, 25, 50) for dry, (25, 50, 50, 75) for moist and (50, 75, 100, 100) for wet.

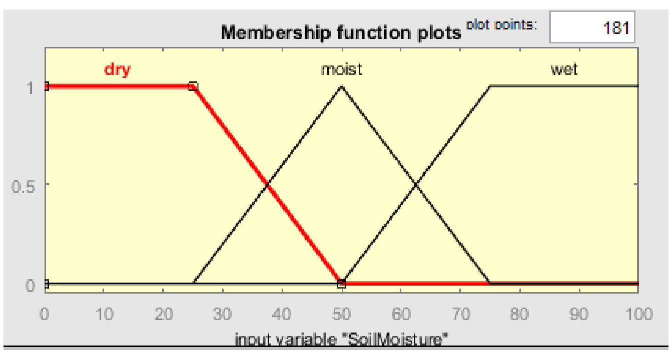

Fig.5 Input Membership Function for Soil Moisture

Figure 6 displays the input membership function for the temperature of the room. The membership function used in fuzzifying the temperature is the same with the moisture of the soil, which is trapezoidal, which is also divided into 3 degrees of membership and represented as: Hot, Mid, Cold. The fuzzy input variable used is the average temperature. Degrees of membership for temperature is (0, 0, 25, 30) for cold, (25, 30, 30, 35) for normal, and (30, 35, 40, 40) for hot.

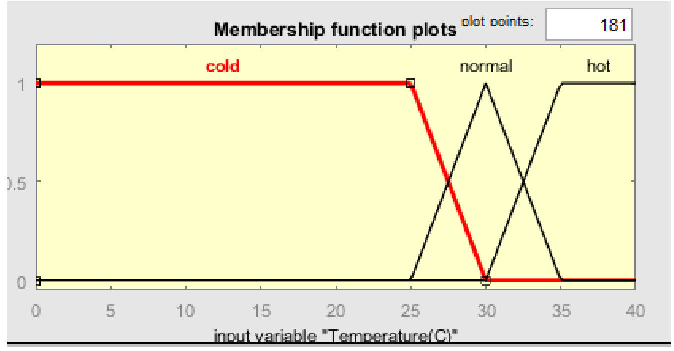

Fig. 6 Input Membership Function for Room temperature

D. Fuzzy Rules and Antecedents

Table 1 shows Fuzzy Rules and Antecedents of the input and output membership functions. It is composed of 2 different inputs with 3 degrees of membership each which results to 9 possible outputs. The table explains the If and then statements of the fuzzy inference of the system. IF hot & dry, THEN large, for other cases, the process is the same. The fuzzy rules use AND logic.

Table 1. Fuzzy Associative Matrix

	Dry	**Moist**	**Wet**
Hot	Large	Medium	Medium
Mid	Large	Medium	Little
Cold	Medium	Little	Little

E. Defuzzification

Defuzzification is the changing of value from the fuzzification into crisp data. Method of center of gravity was used for defuzzifying. The center of gravity method used the ratio between the total of each outcome's grade of the rule times the actual output counts to the sum of the outcome's grade.

Figure 7 displays output membership for the water volume. Triangular membership function is used for the fuzzy output because of its simplicity and more definite output other than the trapezoidal which has a large range of value. The volume of water is represented by a linguistic variable little, medium, and large. The degrees of membership are (1, 3, 3, 5) for small amount, (3, 5, 5, 7) for medium amount, and (5, 7, 7, 10) for large amount.

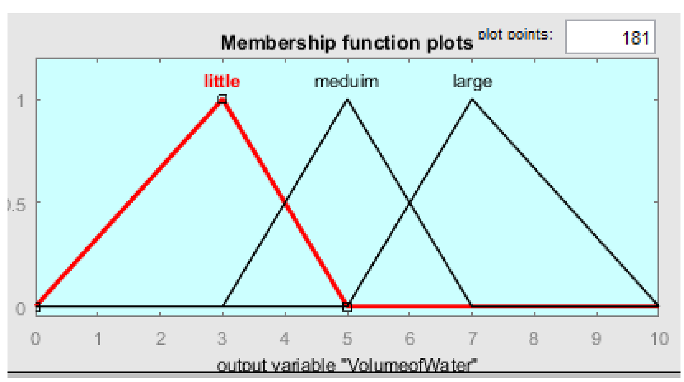

Fig. 7 Output Membership Function for volume of water

F. Graphical User Interface

The GUI toolkit used for displaying the data is called Tkinter. The toolkit uses Python as the programming language and uses button commands for displaying the data in the table. The toolkit also uses MySQL connector package for connecting the GUI to the database.

IV. RESULTS AND DISCUSSION

A. Fuzzy Logic

Table 2 shows the accuracy of a water flow sensor with an average percentage error of 5.58%. The data measured from the water flow sensor of the system was compared to a bottle of water with its volume measured.

Table 2. Accuracy Test for Water Flow Sensor

Trial	Actual	Measured	Percent Error
1	500	522	4.40
2	680	712	4.71
3	725	759	4.69
4	910	914	0.44
5	750	900	20.00
6	870	890	2.30
7	720	702	2.50
		Average:	5.58

Table 3 shows the accuracy test for soil moisture sensors. The commercialized soil moisture sensor was compared to the average of the three soil moisture sensors of the system. According to the data shown, the overall percent error is approximately 5.8%.

Table 3. Accuracy Test for Soil Moisture Sensor

Trial	SM1	SM2	SM3	ACTUAL	Difference
1	68	68	66	60	0.12222222
2	87	87	85	85	0.01568627
3	85	85	83	80	0.05416667
4	71	72	69	65	0.08717949
5	78	79	75	75	0.03111111
6	72	72	70	70	0.01904762
7	88	83	84	85	0
8	40	46	48	50	0.10666667
9	60	60	68	60	0.04444444
10	60	65	74	60	0.10555556
11	60	63	74	65	0.01025641
12	54	60	64	60	0.01111111
13	49	58	65	50	0.14666667
14	48	57	63	50	0.12
15	51	61	68	60	0
				% Error	5.82742824

Table 4 shows the accuracy test for the temperature sensor. The data from the sensor of the system was compared to a room thermometer. The percentage error is 0%.

Table 4. Accuracy Test for Temperature Sensor

Program	Actual
26	26
26	26
27	27
28	28
27	27
26	26
27	27
26	26
26	26
26	26

B. Graphical User Interface

Figure 9 shows the User interface for the drip irrigation system which displays the data being measured by the sensors, such data like soil moisture and room temperature which is the input parameters to the algorithm flow rate and output volume of water which is the output parameter from the algorithm. The data will be then stored in a database.

Fig.9 Design of the GUI

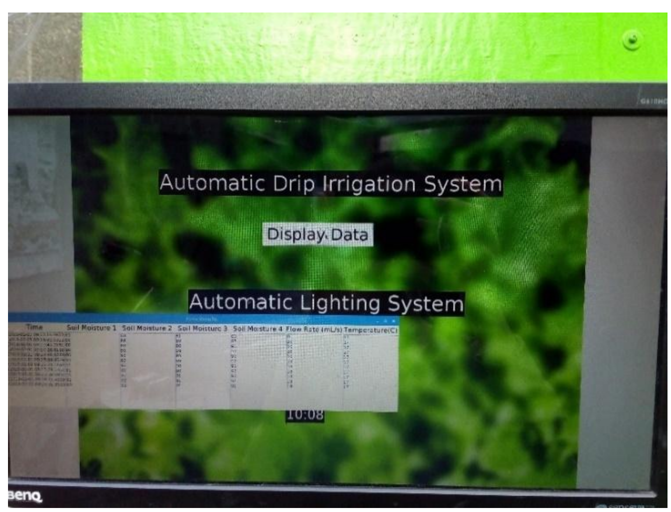

Fig.10 Data shown on GUI

C. Plant Parameters (Chamber)

Table 5 shows the measured plant parameters from the plants inside the chamber. These plants used the automated irrigation system with the use of fuzzy logic flow control.

Table 5. Plant parameters (Chamber)

Day	Height (mm)	Canopy Area(mm^2)	Plants Fresh Weight	Plants Dry Weight
0	0	0	0	0
5	20.32	141.45	-	-
10	25.97	342.5	-	-
15	33.66	829.54	-	-
20	42.25	1528.3	-	-
25	52.49	2738.7	-	-
30	66.23	5081.4	-	-
35	81.72	9056.9	-	-
40	101.92	16402	11.3	0.4
45	97.08	23194	-	-
50	121.29	43469	-	-
55	150.91	79416	67.1	8.4

D. Plant Parameters (Conventional)

Table 6 shows the measured plant parameters from the conventional method of irrigation. The method used for these data is manual irrigation.

Table 6. Plant Parameters (Conventional)

Day	Height (mm)	Canopy Area(mm^2)	Plants Fresh Weight	Plants Dry Weight
0	0	0	0	0
5	20.16	141.06	-	-
10	27.08	442.12	-	-
15	33.05	827.82	-	-
20	40.49	1539.37	-	-
25	50.20	2539.47	-	-
30	61.46	4314.37	-	-
35	74.63	7167.33	-	-
40	89.63	11999.88	3	0.3
45	82.90	16254.34	-	-
50	102.50	25650.04	-	-
55	125.50	41922.70	19.4	3.0

Equations 1 and 2 shows the formula for Crop and Relative Growth Rate, respectively.

Crop Growth Rate:

$$\frac{W_2 - W_1}{A(t_2 - t_1)} \quad (1)$$

Relative Growth Rate:

$$\frac{ln(W_2 - W_1)}{t_2 - t_1} \quad (2)$$

where:
W_2 =Final dry weight
W_1 =Initial dry weight
t_2 =Final time
t_1 =Initial time
A =Ground area

Figure 11 shows the graph for comparison between the plants inside the chamber and plants outside the chamber. Based on the graph of their heights, the plants inside the chamber is way better than the plants in traditional method of irrigation.

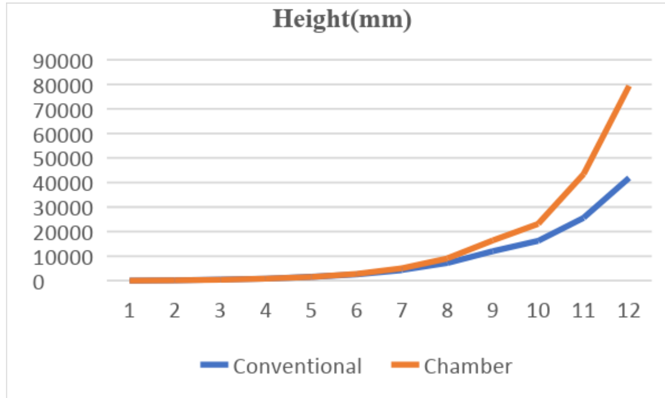

Fig 11. Comparison between heights of plants in mm

Figure 12 displays the graph for height of lettuce in both traditional and inside the chamber. Based on the graph of their Canopy Area, the plants inside the chamber is way better than the plants in conventional method of irrigation.

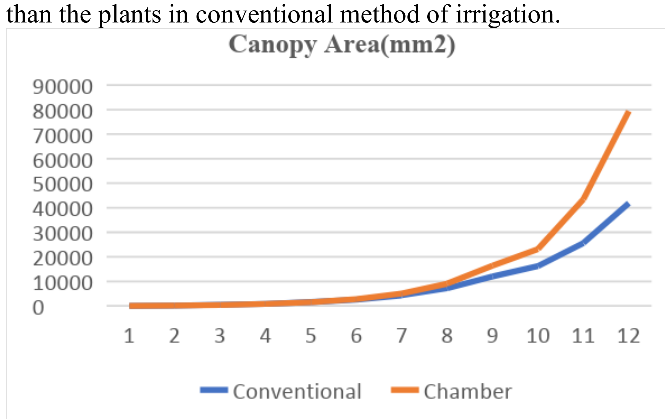

Fig 12. Comparison between canopy area of plants in mm^2

V. CONCLUSION

A Fuzzy-based drip irrigation system is proven to be better than the conventional or traditional method. Manpower is lessened in growing crops. The system is automated and almost thinks how a human brain works. Also, the output of volume - based is better than the output of time-based since the pressure is not consistent. If time-based is used, the pressure of water can make the crops overwatered or underwatered since it has no volume limiter, in a volume-based output with a volume limiter, the crops will receive an exact amount of needed water, thus giving a higher chance of harvesting a quality crop. Also, the valves will only close if the measured value of the flow sensor met the output of the fuzzy. In conclusion, volume-based irrigation is much better, also the system is proven to be accurate since it matched the actual value of soil moisture and temperature. The fuzzy is not just Dry or Wet, Cold or Hot, but fuzzy considers the values between Dry and Wet, Cold and Hot like not that dry, not that wet or not that cold, not that hot, etc. Lettuce inside the chamber has a 9-13% higher height growth rate compare to the growth rate in the conventional method. To summarize, the Fuzzy Logic - based drip irrigation system can be concluded as effective and efficient.

VI. References

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