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Fuzzy Control of Farm Irrigation System

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Abstract:- The food security problem of Nigeria keeps increasing. Recently Nigerians are going back into Agriculture not only as ameans of livelihood but as income generating venture. Farming is a seasonal venture in which during dry season, planting is not possible. To solve this problem, many farmers have started alternative way of getting water through irrigation. In norther part of Nigeria, the amount of rainfall is minimal. The objective of this work is to increase high crop productivity by devising proper automated irrigation system that can be used for proper crop irrigation in the aforementioned areas. This is to increasese the food supply to Nigeria populace. In this work, the design and simulation of a farm irrigation system being controlled by a Fuzzy Control system is carried out using MATLAB (Matrix Laboratory), Seeeduino microcontroller board and Arduino components. A case study of the project was carried out in FUTA Computer science lab. The observed result showed that the Irrigation system can be adequately controlled by the Fuzzy system.

***Keywords*:-** *Fuzzy Logic Mamdani Control System · FIS · Farm Irrigation System · MATLAB · Agriculture · Computer Science · Embedded System · Arduino · Seeeduino.*

I. INTRODUCTION

To alleviate poverty, the current government in Nigeria is laying much emphasis on farming. The impact of agriculture in a sustainable means is undebatable. Agricultural sector is one of the major contributions to Nigerian economy.

According to [54], the country still imports what it can produce and this is displacing local production while creating unemployment and a weak exchange rate. Currently, Agricultural Sector in the Nigerian economy is largely subsistent.

Nigeria depend on rainfall for farming. Agriculture in Nigeria is seasonal and vulnerable to climate change impact. This has resulted into Nigeria farmers using irrigation as alternative supply of water to the farm especially during the dry season.

The manual control of water pumps by farmers may lead to inadequate water supply or too much flow of water to the land which damage the crops. Lack of adequate water supply may lead to deterioration of plants growth before visible wilting, slow growth and light weight fruit yields. Maintaining adequate supply of water level in soilis needed for maximum yield from crop production.

In this research, an irrigation system being controlled by a fguzzy logic control system is presented to solve this problem. To carry out the research, Direct Current (D.C) power will be used as a source for water pumping, water pumping will be used as a tool for pumping the ground water to fill the tank. Several pump models are currently been used. In the first model, the water pump is operated by turning on and turning off the machine manually. In the other model, the water pump is equipped with a floating ball acted as a physically tap when the water has filled a tank. The manual method is not efficient because the water pump cannot be operated automatically.

In this research, the system includes the fuzzy logic simulation and design and implementation of the hardware prototype using the components: Microcontroller board, LCD display, LED indicator, soil moisture sensor, DHT sensor, ultrasonic sensor and 12V DC submersible water pump.

The hardware system should perform the following functions: (1) determine if water is needed by the plants, (2) monitor the water level in the tank, (3) supply amount of water needed by the plants, (4) turn off the water pump when the required amount of water has been pumped to the plants.

II. RELATED WORKS

[27] designed and implemented an automatic farm irrigation and soil moisture system being controlled by Arduino using soil moisture sensor and L293D module. The limitation of this work is that the soil humidity and temperature were not considered before water is applied to the soil.

[30] designed and developed a smart system for irrigation using 8051 Microcontroller and a fencing control using Bluetooth Module. A soil moisture sensor was also considered in the work using soil moisture sensor and

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L293D module.

➢ *The Pumping System Pumps Water from well to Water Tank.*

The water level is detected using ultrasonic sensor. This automatic irrigation system senses the moisture content of the soil and automatically switches the pump when the power is on. The limitation of this work is that 8051 Microcontroller is very slow. More so the 8051 Microcontroller needs an external EEPROM to store even 1 byte of data. In addition, more functions are needed to access the EEPROM. All these make 8051 Microcontroller inefficient for this type of research. Also, the irrigation system make use of an Analog-Digital Converter (ADC) which involves rigorous process compared to other advanced microcontrollers.

[53] carried out a research on performance evaluation of Irrigation System. The researcher observed the discharge of water and recorded at seven selected monitoring sites for determining water delivery metrics being used for Welenchity Irrigation System. Discharge was monitored and measured by using a Discharge App. The work only measures performance.

[31] developed a controller for solar irrigation System. The researcher implemented the system using soil moisture control sensor and L293D module by Arduino. The system made use of water level indicator and its pumping system from well to water tank. Limitation is that the researcher didn't consider other important factor like temperature and humidity of the soil before watering the plant.

[57] developed automatic plant watering system using Arduino. The motivation for the work was to reduce the labour task associated with the traditional irrigation system. The researcher adopted ATmega 328 microcontroller was programmed to sense the moisture level of the plants and supply the needed amount of water if need be. The work however failed to consider temperature and humidity of the soil before watering the plant.

This research therefore is being motivated by the need to develop a hardware prototype and fuzzy control system that effectively addressed some of the limitations of the reviewed systems. More specifically, the objective of the research was to design and develop a fuzzy controller of an irrigation system for crop productivity. The proposed system will be simulated in MATLAB based on the Mamdani and Sugeno Control Fuzzy Inference Systems. The results obtained from the two systems will be compared to find out which fuzzy inference system is the most effective.

III. THE PROPOSED MODEL

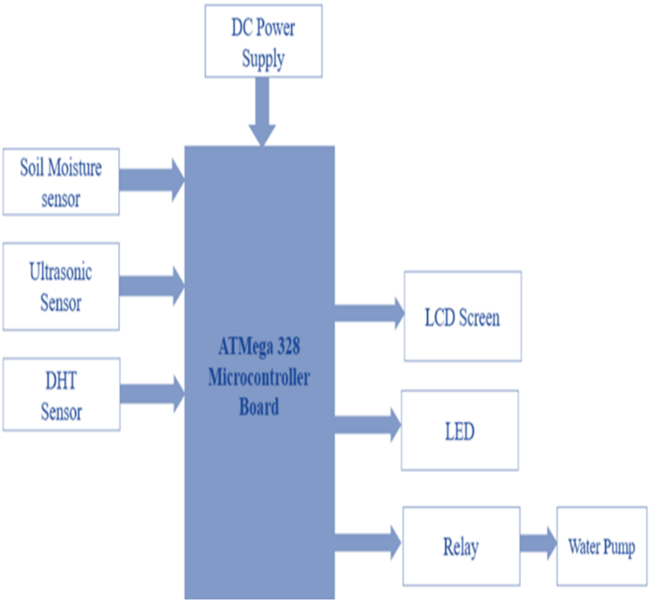

Fig 1 Architecture of Fuzzy Control System

The architectural of the proposed system is presented in Fig.1. It shows the input and output components connected on the ATMega 328 microcontroller board.

➢ *Fuzzy Logic*

The idea of fuzzy logic was invented by Professor L. A. Zadeh of the University of California at Berkley in 1965 [12]. Fuzzy logic draws conclusions and generate responses based on unclear, incomplete, ambiguous, and imprecise information.

In the real world many times we encounter a situation when we can't determine whether the state is true or false, their fuzzy logic provides a very valuable flexibility for reasoning.

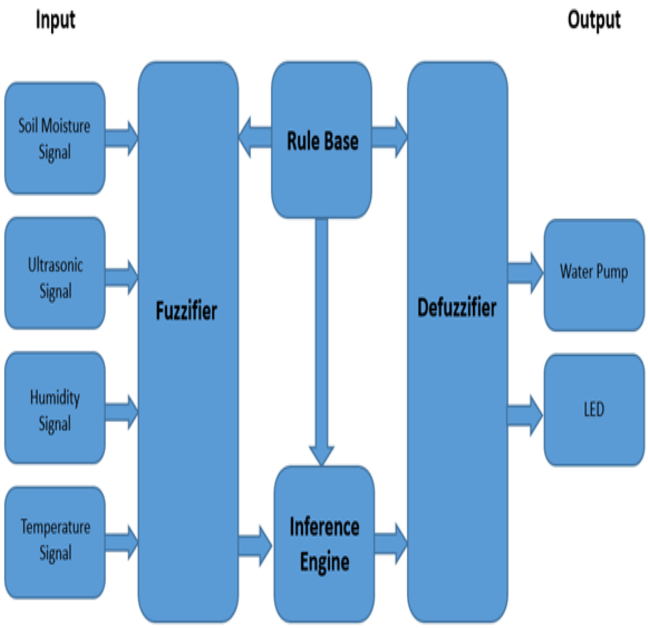

Fig 2 Block Diagram of the Proposed Fuzzy Controller for Farm Irrigation System

The intelligent component of the system is the fuzzy reasoning unit which comprises of the rule base and database. The fuzzy unit translates inputs into fuzzy real values while the rule base is used to compute the output real values. The defuzzification unit transforms the output values into crisp values. Sugeno output is the crisp number found by multiplication of each value of input by constant value and finally adding up the values. The advantages of using Sugeno method is that it could be used in case of mathematical analysis and is suitable for adaptive techniques [70].

As shown in the Fig. 2, the algorithm of the system is presented as follows. Four sensors were used to collect data. The sensors are: Soil Moisture sensor, Ultrasonic Sensor, Humidity Sensor and Temperature Sensor.

One major parameter which is the Water Pump Rate is considered as the output.

$$\alpha = x_1 A_1 \quad (1)$$

$$\beta = x_2 A_2 \quad (2)$$

$$\gamma = x_3 A_3 \quad (3)$$

$$\theta = x_4 A_4 \quad (4)$$

- Where x_1 = Soil Moisture sensor, $x_2 =$ Ultrasonic sensor,
- x_3 = Temperature sensor, x_4 = Humidity sensor
- $\alpha, \beta, \gamma, \theta$ are the result from the membership function of soil moisture sensor
- β = result from the membership function of ultrasonic sensor
- γ = result from the membership function of Temperature sensor
- θ = result from the membership function of Humidity sensor

- A_1 = Input signal membership function of soil moisture sensor
- A_2 = Input signal membership function of ultrasonic sensor
- A_3 = Input signal membership function of Temperature sensor
- A_4 = Input signal membership function of Humidity sensor
- A_i = is the membership function signals from input components (sensors).

Where x_i $(i = 1, 2, 3, 4, \dots, n)$ is the input variables i.e. signals from the Soil moisture sensor, Ultrasonic sensor and Temperature sensor, Humidity sensor etc.

$$S = \alpha+\beta+\gamma+\Theta \quad (6)$$

$$y = v + \sum_{i=1}^{m} S \quad (7)$$

y is the output variable obtained by the fuzzy rule. While s = result from sum of the membership function of all the sensors used.

A_i = is the membership function signals from input components (sensors)

v is a constant value (crop type)

The final output of the fuzzy model is inferred by a weighted average defuzzification.

$$z = \frac{\sum_{i=1}^{n} w_1 y_1}{\sum_{i=1}^{n} w_1} \quad (8)$$

Where weight (w) implies the overall truth value.

z is the final output value of the true detections from the sensors.

The proposed model consists of four major parts:

- *Fuzzification*

It is used to convert inputs i.e. crisp numbers into fuzzy membership values. Crisp inputs are obtained from the sensors. These sensor inputs are passed to the rule-base which consists of the conditional IF-THEN statement. Several fuzzy membership functions are used which include Gaussian, Triangular and Trapezium membership.

In this research, it was used to convert input from soil moisture sensor, ultrasonic sensor and temperature and humidity sensor respectively. Then input parameters are described by at least three linguistic regions as illustrated in Table 1.

Table 1 Input and Output of Fuzzy System using Mamdami and Sugeno Methods

INPUT	Measured As	Region	Linguistic Variable
Soil Moisture	Centibars	[0 25 50 100]	Dry Low Adequate Saturated
Relative Humidity	%	[0 50 100]	Low Medium High
Temperature	°C	[0 20 40 60]	Very Cold Cold Normal

			Hot
Ultrasonic	Mm	[0 50 100]	Low Medium High
OUTPUT	Measured As	Range	Linguistic Variable
Open Water Pump	%	[0 25 50 75 100]	25% open 50% open 75% open 100% open

➢ *Membership Function and Fuzzy Inputs*

Fuzzy inputs include the following:

- *Soil Moisture*

The range for soil moisture is between 0 to 100 Centibars and the type of membership function is Trapezium MF for Mamdani and Gaussian for Sugeno as denoted as trapmf and gaussmf respectively.

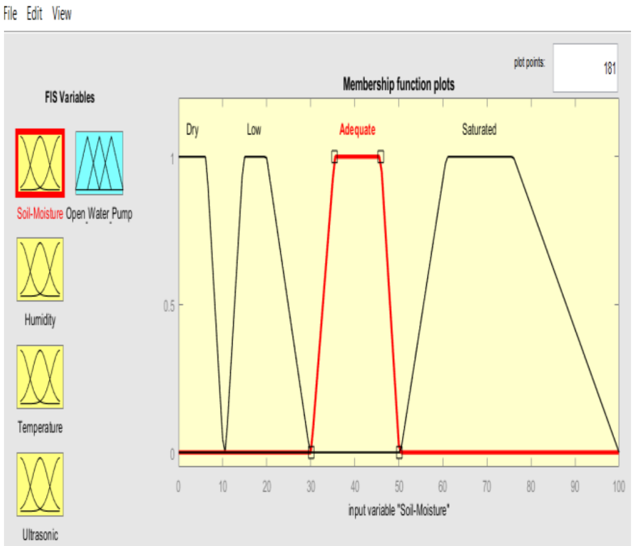

Fig 3 Membership Function plot for Soil Moisture using Mamdani

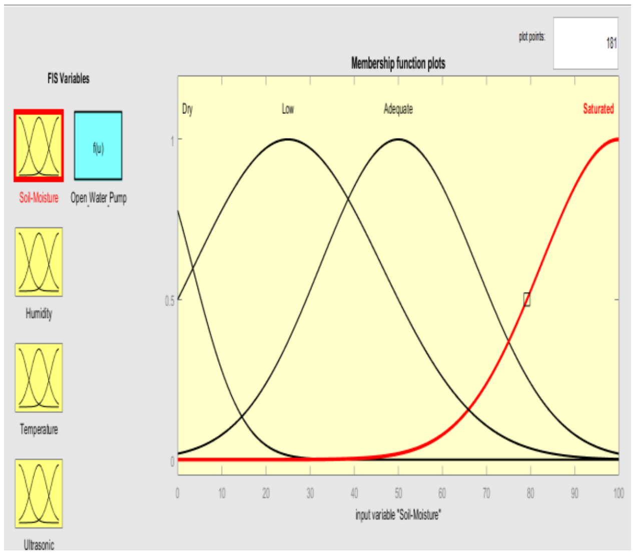

Fig 4 Membership Function plot for Soil Moisture using Sugeno

- *Relative Humidity Around the Soil*

The range for relative humidity is between 0 to 100 % and the type of membership function is Triangular MF for Mamdani and Gaussian for Sugeno as denoted as trimf and gaussmf respectively.

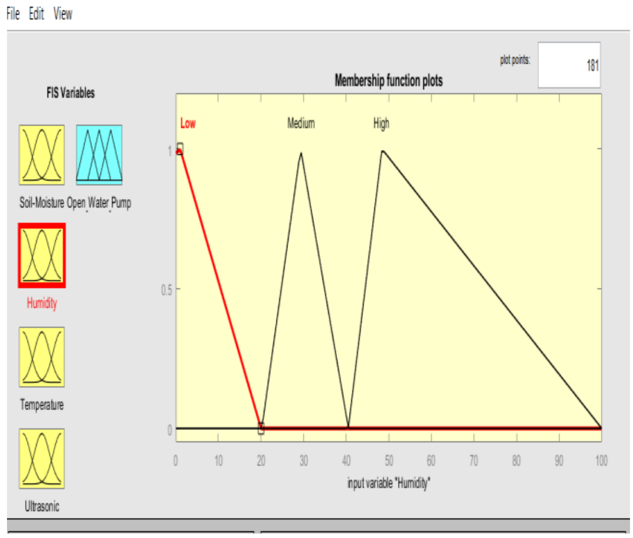

Fig 5 Membership Function plot for Humidity around the soil using Mamdani

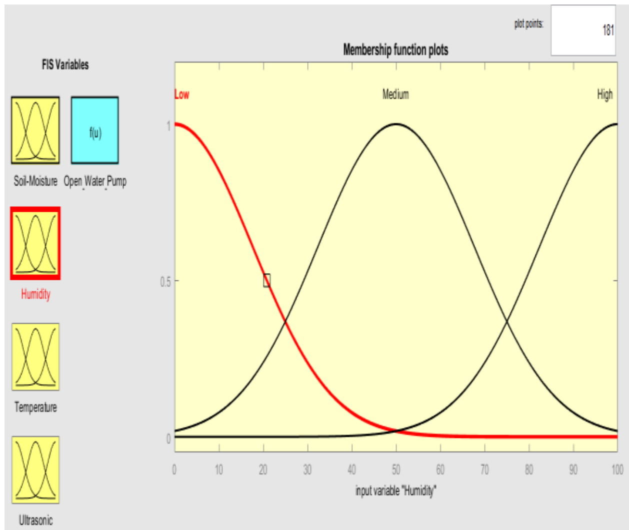

Fig 6 Membership Function plot for Humidity around the soil using Sugeno

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- *Temperature Around the Soil*

For a wide variety of seeds, there are various temperatures that are optimal for germination of the seeds. If the temperature around the soil is high, the soil moisture will evaporate, the water balance gets affected. Thus in the fuzzy logic control, Temperature is an important factor to be considered while watering the yields. Temperature is expressed as °C.

The range for temperature of the soil is between 0 to 60 degree Celsius and the type of membership function is Triangular MF for Mamdani and Gaussian for Sugeno as denoted as trimf and gaussmf respectively.

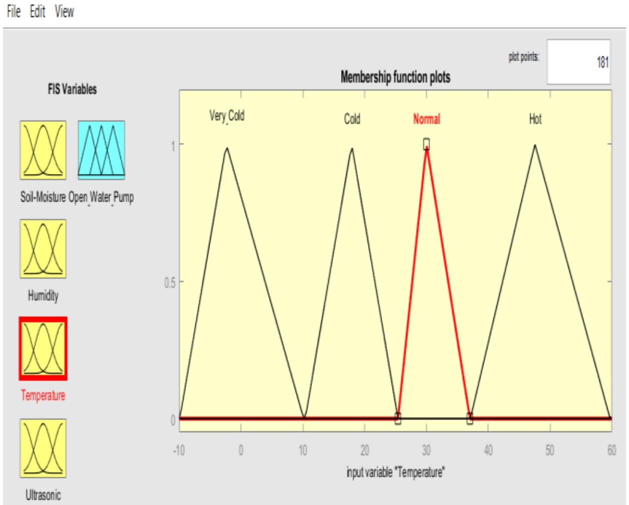

Fig 7 Membership Function plot for temperature around the soil using Mamdani

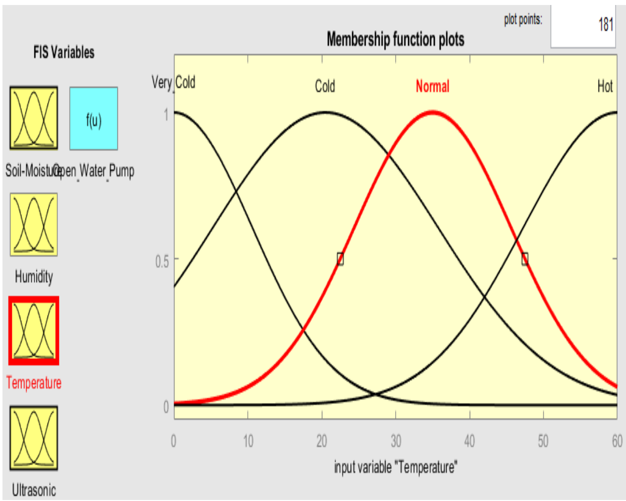

Fig 8 Membership Function plot for temperature around the soil using Sugeno

- *Ultrasonic Signal for Water Tank level*

As shown in Fig. 10, functionality of all membership function for water pump output highly depends on the availability of water in the reservoir. If the water in the tank is full then the water pump will be turned on after satisfying other necessary conditions otherwise it remains turned off. The calibration for the tank is in millimeter. 60mm is the maximum while 0mm is the lowest value and 10mm > and < 40mm is considered to be the average water in the tank.

The range for ultrasonic is between 0 to 100 mm and the type of membership function is Guassian2 MF for Mamdani and Gaussian for Sugeno as denoted as guass2mf and gaussmf respectively.

Fig 9 Membership Function plot for ultrasonic signal for the water tank level using Mamdani

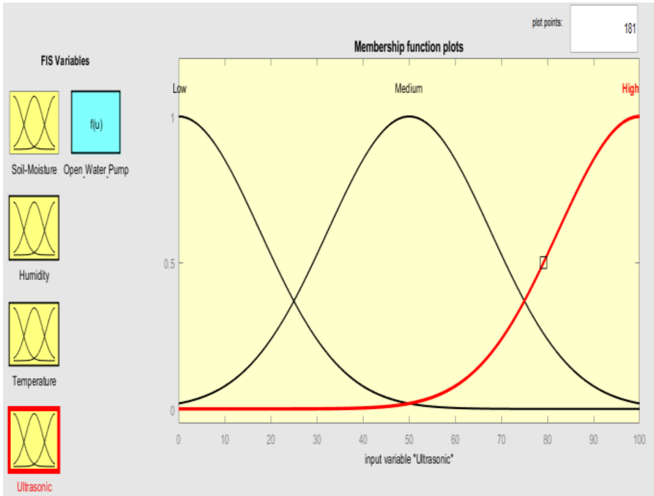

Fig 10 Membership Function plot for ultrasonic signal for the water tank level using Sugeno

- *Rule Base*

It contains the set of rules and the IF-THEN conditions to govern the decision making system that would help solve the problem, on the basis of knowledge and experience.

Examples of the rules are: a) IF soil moisture and humidity is low and temperature is high THEN water control valve opens 90%, b) IF soil moisture, humidity is low, temperature is high and ultrasonic is 60 mm THEN water control valve 0%. Which implies that there is no water in the tank.

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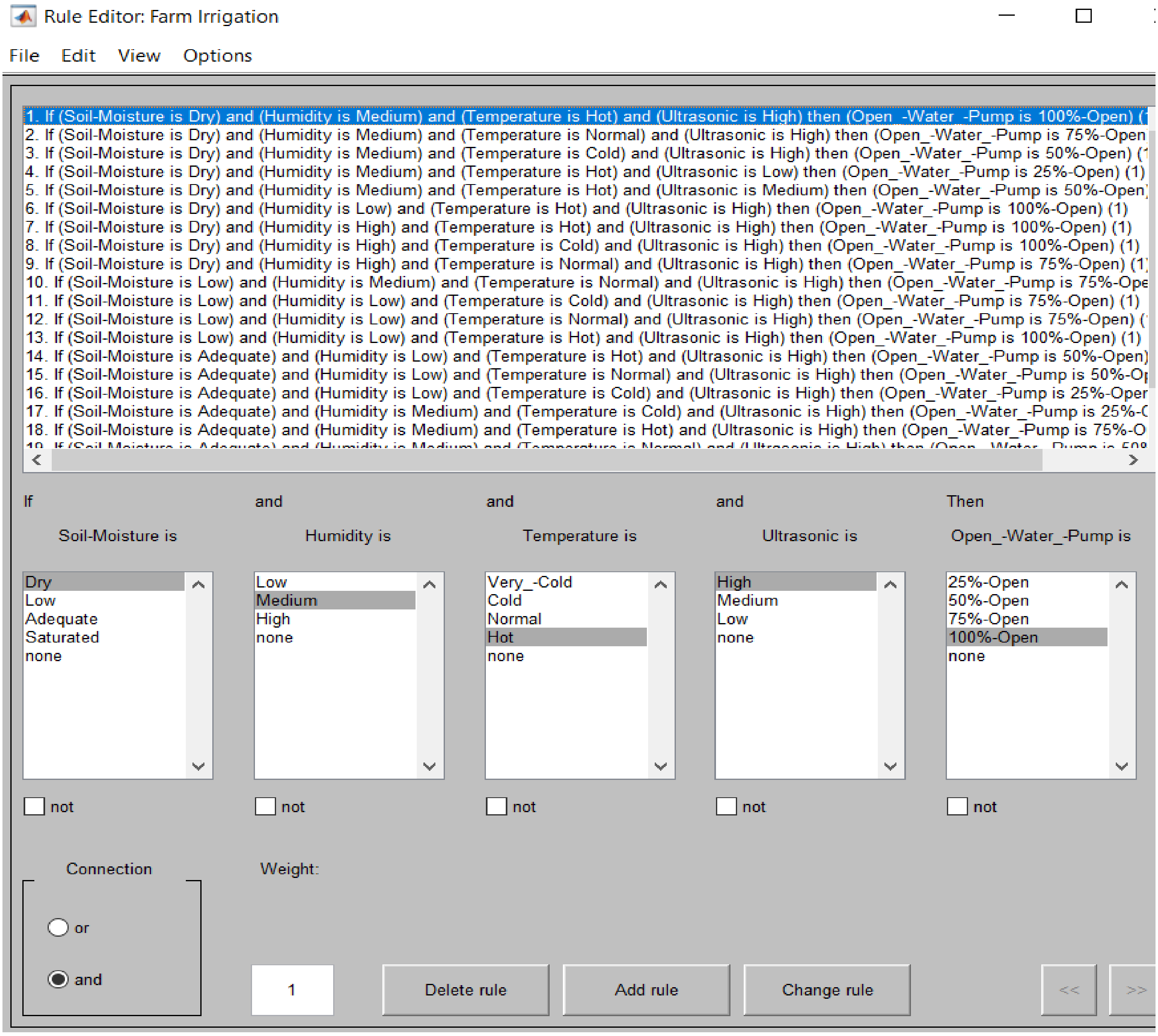

Fig 11 Rule Base Editor

➢ *Inference Engine*

It determines the matching degree of the current fuzzy input with respect to each rule and decides which rules are to be fired according to the input field. Next, the fired rules are combined to form the control actions.

Number of rules = (Number of Fuzzy set) ^ (Number of input parameters).

For this problem, the number of input variables is four, each having at least three specific linguistic regions.

Hence, resulting number of rules will be at least $3^4 = 81$ for the input parameters which is illustrated in fig. 16.

There are two types of FIS namely: Mamdani and Sugeno.

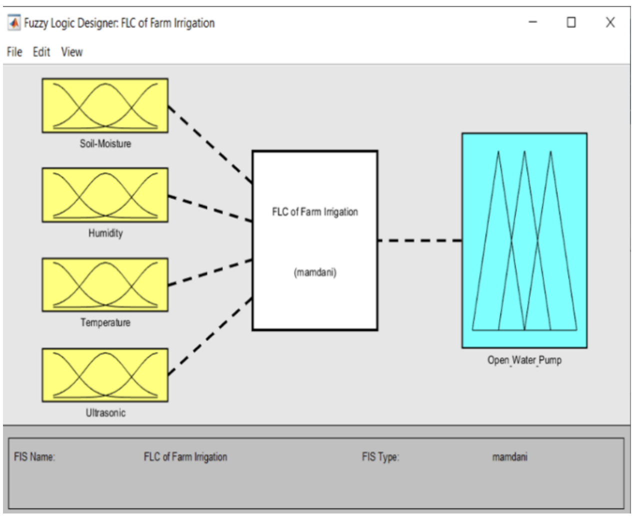

Fig 12 Fuzzy Inference System for the Fuzzy Control Farm Irrigation System using Mamdani Method

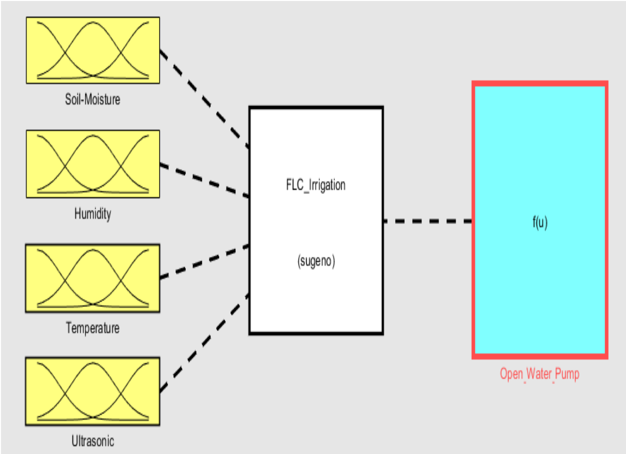

Fig 13 Fuzzy Inference System for the Fuzzy Control Farm Irrigation System using Sugeno Method

➢ *Defuzzification*

It is used to convert the fuzzy sets gotten from the inference engine into a crisp (non-fuzzy) value.

Crisp Output is the water pump rate.

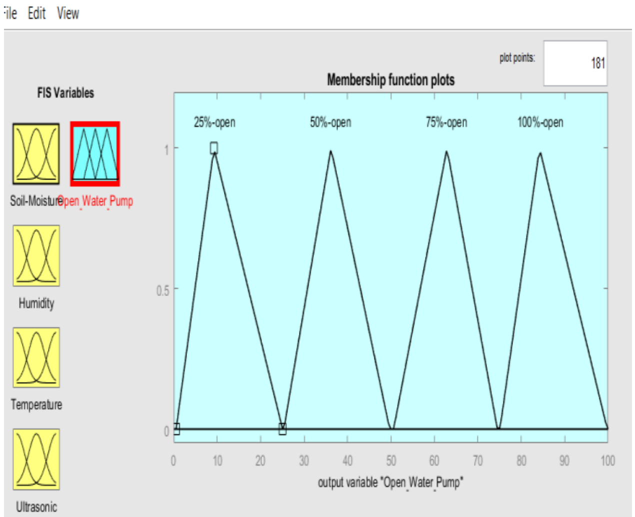

Fig 14 Membership Function plot for output for Mamdani method

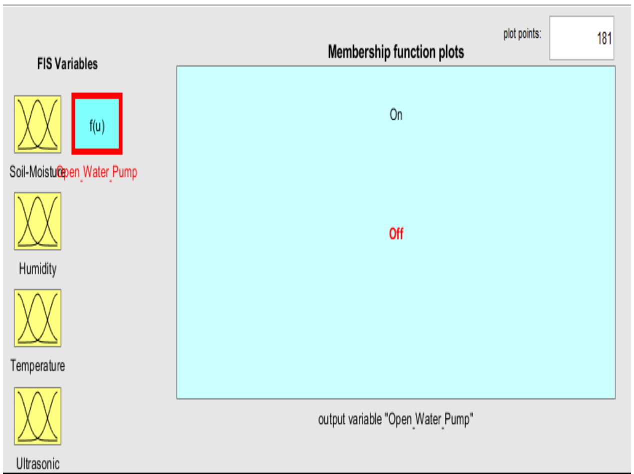

Fig 15 Membership Function plot for output for Sugeno method

➢ *Hardware Prototype*

A prototype of Fuzzy Logic Control of automated Farm Irrigation System was designed. It takes a maximum of one second for all the sensors used to detect the level of the moisture in the soil using the soil moisture and sends a signal to the microcontroller for the appropriate action to be taken. The soil texture considered in the case study of this research is Loamy soil.

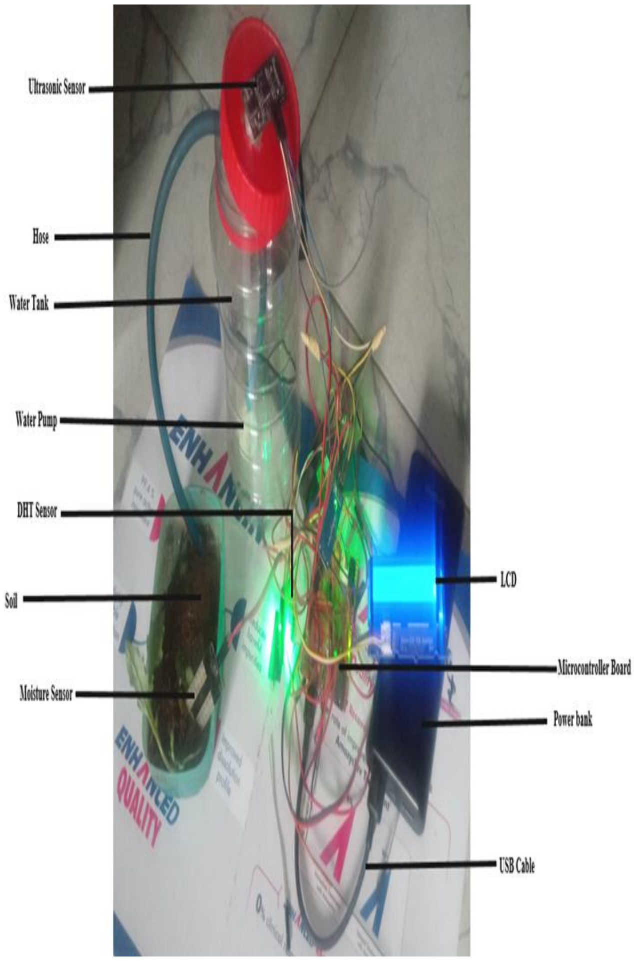

Fig 16 Hardware Prototype Setup

• *Hardware Prototype Result*

As shown in the fig. 17, while the temperature is 30°C, Humidity at 27%, and soil moisture is at its lowest level 1%, this implies that there is no water available in the soil. Hence, the water pump is turned on automatically to water the soil.

Fig 17 Water Pump ON

As shown in the fig. 18, while the temperature is 34°C, Humidity at 25%, and soil moisture is at its lowest level 56%, this implies that there is more water available in the soil. Hence, the water pump is turned off automatically to avoid excess water in the soil and water wastage.

Fig 18 Water Pump ON

IV. SIMULATION RESULTS

As shown in the fig. 19, when the soil moisture content is medium, 30-50 centibars, humidity and temperature is also medium, then the water pump opens only 50%.

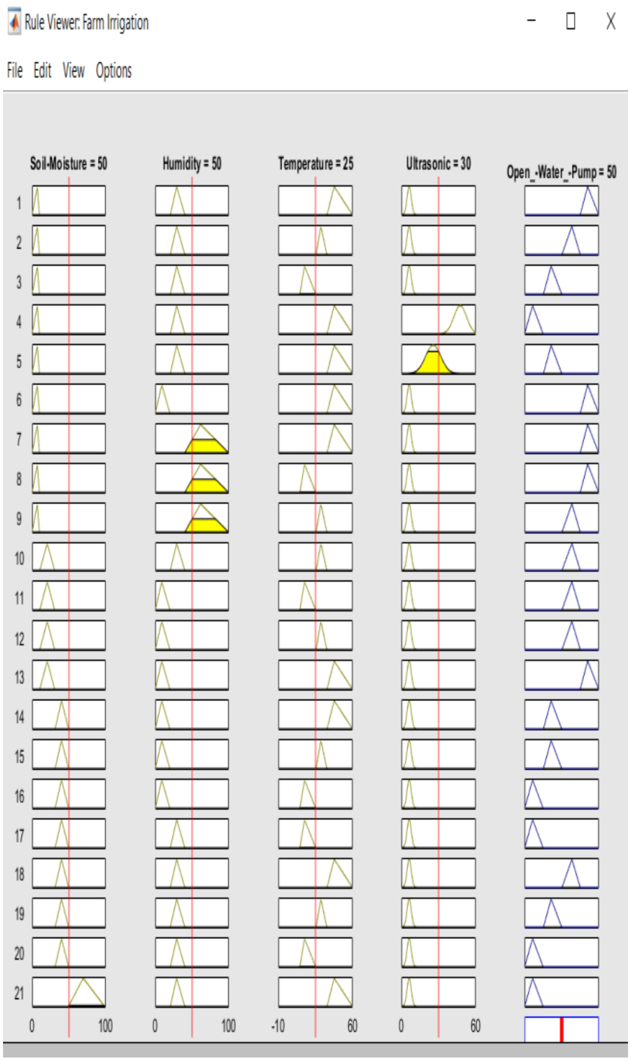

Fig 19 Rule View (50% Water Pump Open)

When the soil moisture content is very low, 0-30 centibars, humidity is also very low and the temperature is high, around 50 °C, then the water pump opens by 87.5%. To compensate for the evaporation of water taking place in the soil due to high temperature, soil dryness the water pump is 87.5% open.

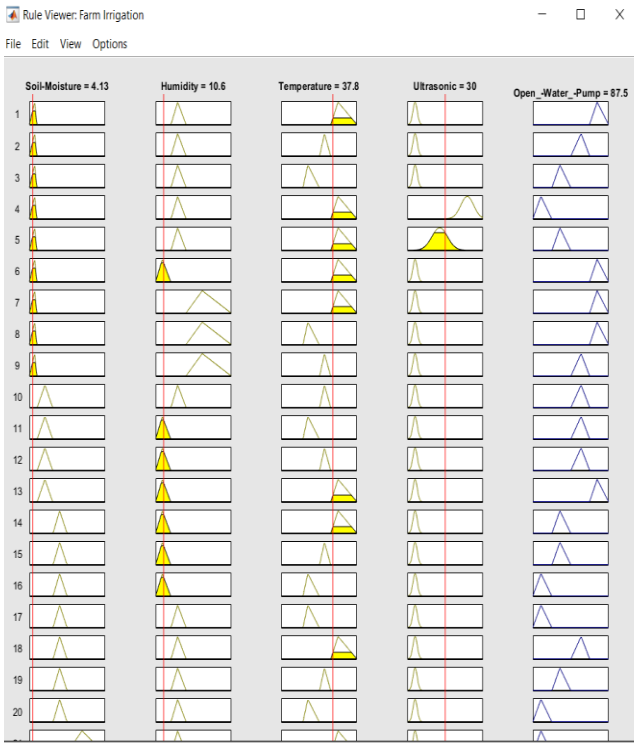

Fig 20 Rule View (87.5% Water Pump Open)

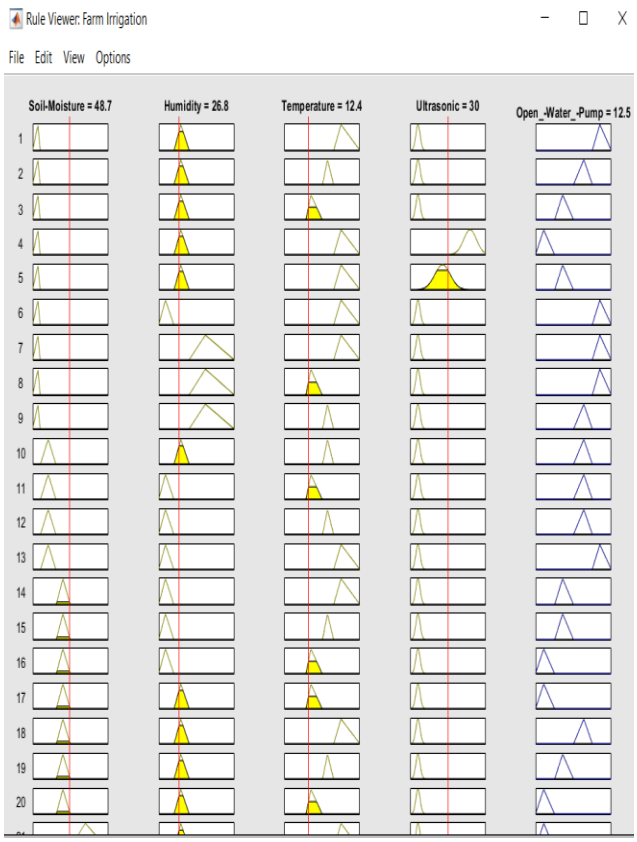

Fig 21 Rule View (12.5% Water Pump Open)

➢ *System Evaluation*

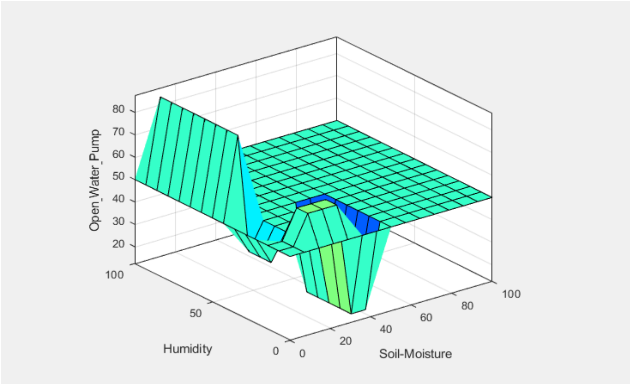

Fig 22 Soil Moisture and Humidity Vs Water Pump using Mamdani Method

From fig. 22, the threshold value is low that means off when the soil moisture and relative humidity decreases. The water pump has a low threshold of 50.

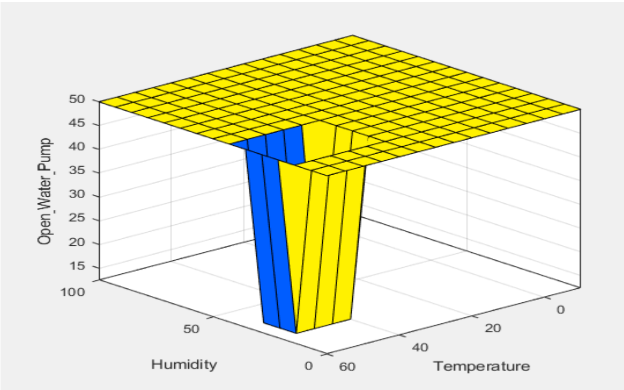

Fig 23 Temperature and Humidity Vs Water Pump using Mamdani Method

From fig. 23, the threshold value is low that means off when the temperature and relative humidity decreases. The water pump has a low threshold of 50.

V. CONCLUSION

In this work, a fuzzy controller system for farm irrigation system has been developed. Four sensors were used to collect data. Moisture sensor to collect the moisture content of the soil. humidity sensor to sense moisture of the air around the soil, temperature sensor to sense the temperature around the soil, and ultrasonic sensor to sense the water level in the tank. This became necessary so that appropriate quantity of water can be released to the soil at the appropriate time. Seeeduino Microcontroller board was used as the computer hardware component of the system. Different membership functions were used in the experiment for the fuzzy variables. These are the triangular, trapezoidal and guassian membership functions. A fuzzy inference is then developed to take the inputs from the membership functions and generate appropriate output. The implementation was carried out in a Matrix platform. Experimental results shows that the system can adequately control the irrigation system.

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