



Implementation of an Automatic Irrigation System Using Embedded Fuzzy Logic

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ABSTRACT

Farming involves labour and time-consuming activities and requires the continuous observation of plants. Regardless of the weather condition, be it hot or cold, it is either too hot or cold or too dry and wet, it is very crucial to control the amount of water that reaches the plants. Hence, the need for an automatic irrigation system that will water plants when they need it. Using fuzzy logic, air humidity air temperature, and soil moisture were observed and monitored, forming the basis upon which watering of the plant was done and in what proportion. This paper implemented a framework that enabled fuzzy logic to control a pump's flow speed according to user-defined variables, using temperature and humidity sensors in the system. The fuzzy logic controller was designed using the Mamdani rule to control the speed of the irrigation motor. PROTEUS was used to simulate a fuzzy controller using the Mamdani model. Membership intervals for a linguistic variable were set and the system was experimented with by varying inputs. The results obtained showed that the proposed system was effective in irrigating agriculture fields using the output provided by controlling the inputs (temperature, soil moisture and humidity).

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INTRODUCTION

Irrigation is very vital as it contributes to the availability of fresh food for human consumption. Despite the huge investment in agriculture in Nigeria, irrigation practices have not been up to par and this makes little or no contribution to the economy of the country (Adelodun and Choi, 2018). Various researches have been carried out on how soil irrigation can be made more efficient. Researchers have used different ideas and different technologies depending on the condition of the soil and the quantity of water (Sudha et al., 2011; Agrawal and Singhal, 2015; Ejofodomi, 2020).

Touati, et al., (2012) designed a fuzzy controller and wireless monitoring strategy to develop an irrigation approach that fosters sustainable improvement in the management of irrigation. The developed fuzzy control strategy optimized the time and duration of irrigation for a given crop. To monitor system performance in real-time and keep a record of key data, a ZigBee

wireless system was developed. Experimental results showed that the deployment of fuzzy control approach combined with wireless monitoring has a great impact on irrigation sustainability through better management and planning.

Jaichandran et al., (2013) proposed a wireless sensor-based automated irrigation system. The system will switch on the irrigation motor based on soil moisture content in the field and the irrigation motor will be switched on when the field moisture level is low and the motor will be switched off when moisture in the field reaches a threshold level. The main limitation of this system was that the availability of water resources is not considered in switching on the irrigation motor.

Khan et al., (2014) proposed a fuzzy-based wireless sensor network (WSN) for intelligent irrigation control. Fuzzy Controller is designed using the Mamdani model in MATLAB. The proposed system controls irrigation using soil moisture values and temperature values send

from WSNs. Soil moisture and temperature are set as linguistic variables and the characteristic of the system is tested by varying the variable range. Reshma and Babu, (2016) proposed an IOT based automatic irrigation system using wireless sensor networks in which various sensors were used to measure the soil parameters. The system provided a web interface for the user to monitor and control the system remotely. Weather monitoring was not done in this system. (Dharrao et al., 2015; Jain et al., 2016) designed an automatic irrigation system using a wireless sensor network to carry out real-time monitoring of the temperature and soil moisture parameters. Depending on the effect of the temperature on the moisture condition of the field, irrigation takes place by the use of wireless communication between nodes.

Abdullah et al., (2020) presented a framework that enables a pump switching time to be controlled according to the input parameters from the soil moisture, temperature and humidity sensors. The system used IoT as the interface with the end-user. A limitation of this system was that a DHT 11 sensor was used which has less accuracy in reading the temperature and humidity.

Based on the reviewed literatures, it is necessary to implement the automatic irrigation system which will take care of plants to help them grow healthy. The use of fuzzy logic will make the irrigation process effective as its deals with how

the human brain thinks unlike the Boolean logic method.

The proposed system aims at detecting the moisture content of the soil, the air temperature and humidity using sensors that are placed directly into the soil. These sensors provide readings for the microcontroller which are de-fuzzified and output is communicated and the motor driver drives the pump and supplies water to the soil. The Arduino microcontroller, controls the connection and interaction between objects in the proposed system, enabling the objects to sense and act. Also, with its powerful onboard processing, various sensors and other application-specific devices can be integrated into it.

The proposed system has application in the agricultural sector as it makes agricultural activities less stressful and time-consuming. The advantages of the system are; an increase in the efficiency of irrigation, reduction in labour required, cost-efficient, and conserve water and electricity.

METHODOLOGY

The study was divided into two parts, the hardware and software parts. The hardware is the physical part of the system while the software part consists of the design of the MATLAB fuzzy logic toolbox and written codes to control the operations of the Arduino UNO ATmega382P microcontroller. The block diagram of the system is presented in Figure 1.

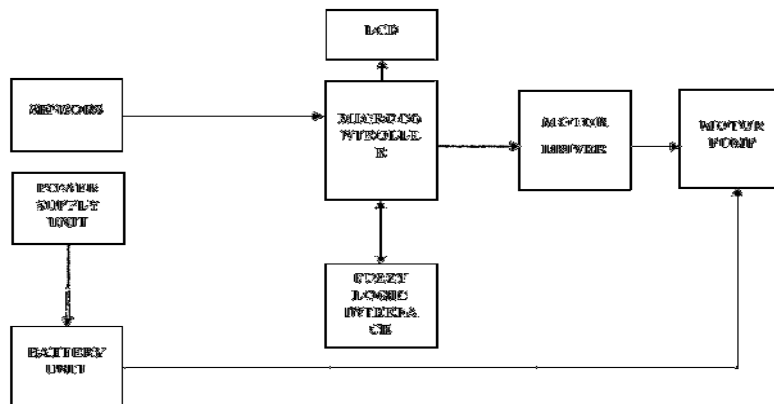


Figure 1. Block diagram of the proposed system

The power supply for the Pump is derived from a DC power supply unit, with output

DC voltages of 2.5V, 5V, and 12V to give a voltage variation control for the irrigation pump. The



various input variable to the system which was the soil moisture content, temperature and humidity was sensed by the soil moisture sensor and DHT22 sensors respectively. The values sensed were sent to the microcontroller which then sends it to the fuzzy logic software through serial communication, with different rules and thus uses the data to know the condition of the various parameters and sends it back to the microcontroller.

The microcontroller then sends the 5V signal to the L298N driver that varies the pump output. The microcontroller receives this input data and compares it with fuzzy rules programmed in its memory to implement the fuzzy logic if true. The speed of the water pump was controlled with the pulse width modulation pin. The PWM speed control works by sending on and off pulses to the motor and varying the duty cycle and the time that the motor is on as compared to when it is off. The DC voltage applied to the motor terminals is varied by varying the width of the applied pulses, hence the longer the pulse is on, the faster the speed of

$$\frac{E_p}{E_s} = \frac{I_s}{I_p}$$

where, $E_p = 220Vac$, $E_s = 112Vac$, $I_s = 1A$. The primary current $I_p = \frac{E_s \times I_s}{E_p} = \frac{112 \times 1}{220} = 54.4mA$.

The rating of the stepdown transformer used is 220/12V, 50Hz and a current rating of 1A.

The peak voltage is $\sqrt{2} \times V_{rms}$

Hence, $V_p = \sqrt{2} \times 12 = 16.97V$.

The biasing voltage for the diode is 0.7V for the silicon diodes, and since it's a full-wave rectifier, two diodes were conducted in each half cycle therefore there were two voltage drops.

So, the capacitor voltage is given by;

$$V_c = 16.97(1.4)V - 1.4V = 22.36V_{dc} \quad (3)$$

Hence the filter capacitor has a voltage of 25V. Note that the 1.4V in the calculations is the voltage drop from the Bridge rectifier IC.

For the filter circuit, to minimize the ripple of the rectified DC voltage by 100% an electrolytic capacitor was used. $\Delta_{rms} = \text{change in ripple voltage}$.

$$\text{At 10\% ripple the rms value} = \frac{10}{100} \times 16.97 = 1.697V_{dc} \quad (4)$$

$$\Delta_{rms} = 16.97 - 1.67 = 15.23V_{dc}$$

To calculate the value of the electrolytic capacitor used

$$C = \frac{I}{2V_{pf}\sqrt{2}} \times f \quad (5)$$

Where, I = current rating of the transformer = 2A, v_p = peak voltage across the rectifier = 15.57V, and f = frequency of the transformer = 50Hz, hence,

$$\text{Capacitance value} = \frac{2}{2 \times 15.57 \times 50 \times \sqrt{2}} = 980\mu f \quad (6)$$

Therefore, an electrolytic capacitor with a capacitance of $1000\mu f$ was used. A battery of 12V/4A was used to supply power for running the system. Figure 2, shows the charging circuit in the power supply unit.

the motor pump and the shorter the pulse is on, the slower the speed of the motor.

The threshold values of the plant for soil moisture range between 40% – 100%, the temperatures is between 15°C – 35°C and humidity of 30RH to 70RH.

The Power Supply Unit

The power supply unit consists of a step-down transformer, a bridge rectifier, the filter circuit, the voltage regulator and the battery. A transformer was used to step down the AC voltage from the mains. A rectifier rectifies the AC voltage to DC voltage, and a voltage regulator was used to maintain a specified DC voltage. The capacitor is used to filter pulsating DC output after rectification while the battery provides an alternate source of power for the system.

Since the power circuit uses a step-down transformer, it receives its input power source from 220V_{ac} mains input and steps it down to 12V_{ac} /1A. The relationship between the voltages and the current is given as

(1)

(2)

(3)

(4)

(5)

(6)

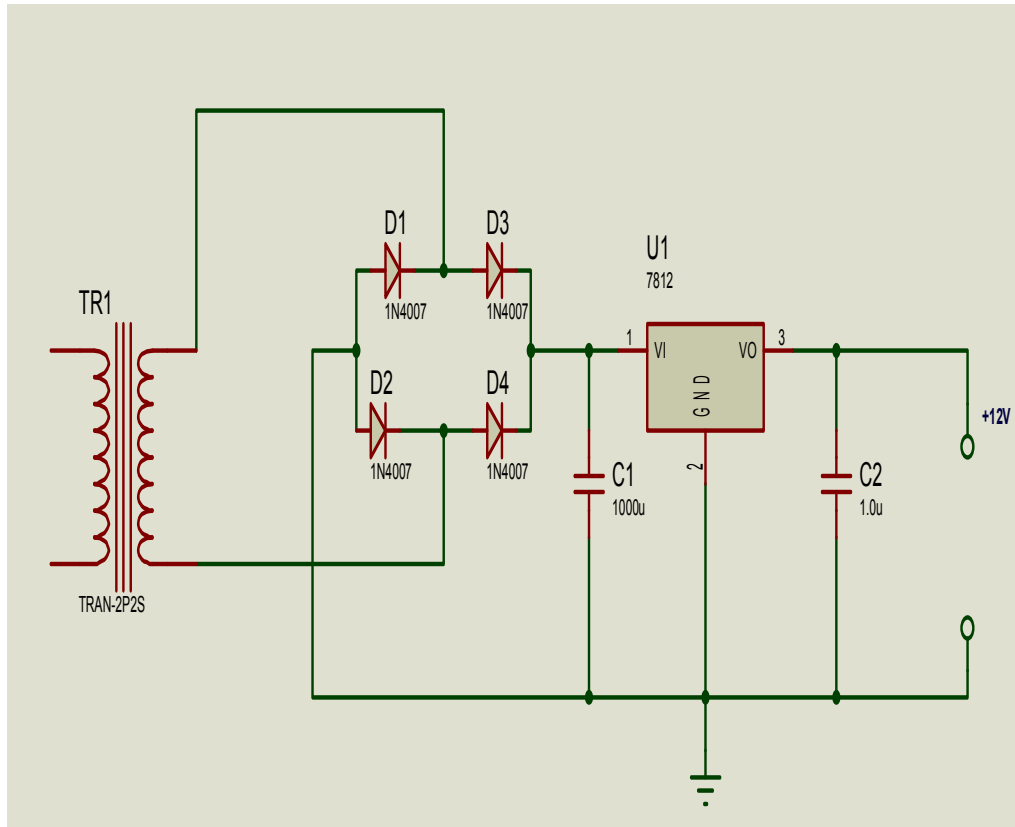


Figure 2. The charging circuit

Software Design

The software design and analysis of the fuzzy algorithm was carried out using Proteus fuzzy Logic system designer and expert knowledge of the optimal conditions required for Plant growth. The system consists of three sub-Fuzzy controllers namely; the soil Moisture system

fuzzy controller, the temperature system fuzzy controller and the humidity fuzzy controller. The Proteus 8 software and C programming language was used in this design. The design fuzzy logic algorithm carried out in MATLAB is presented in Table 1 and the flowchart of the control process in Figure 3.

Table 1: Fuzzy logic algorithm

FUZZY LOGIC ALGORITHM	
1	Define linguistic variable terms
2	Construct membership functions
3	Construct rule base
4	Convert crisp data to fuzzy values using fuzzy membership functions
5	Evaluate rule in the rule base
6	Combine the result of each rule
7	Convert output data to non-fuzzy data

In Figure 4, the circuit diagram for the automatic irrigation system using fuzzy logic is

shown, while Figure 5 is the flow chart of the program design.

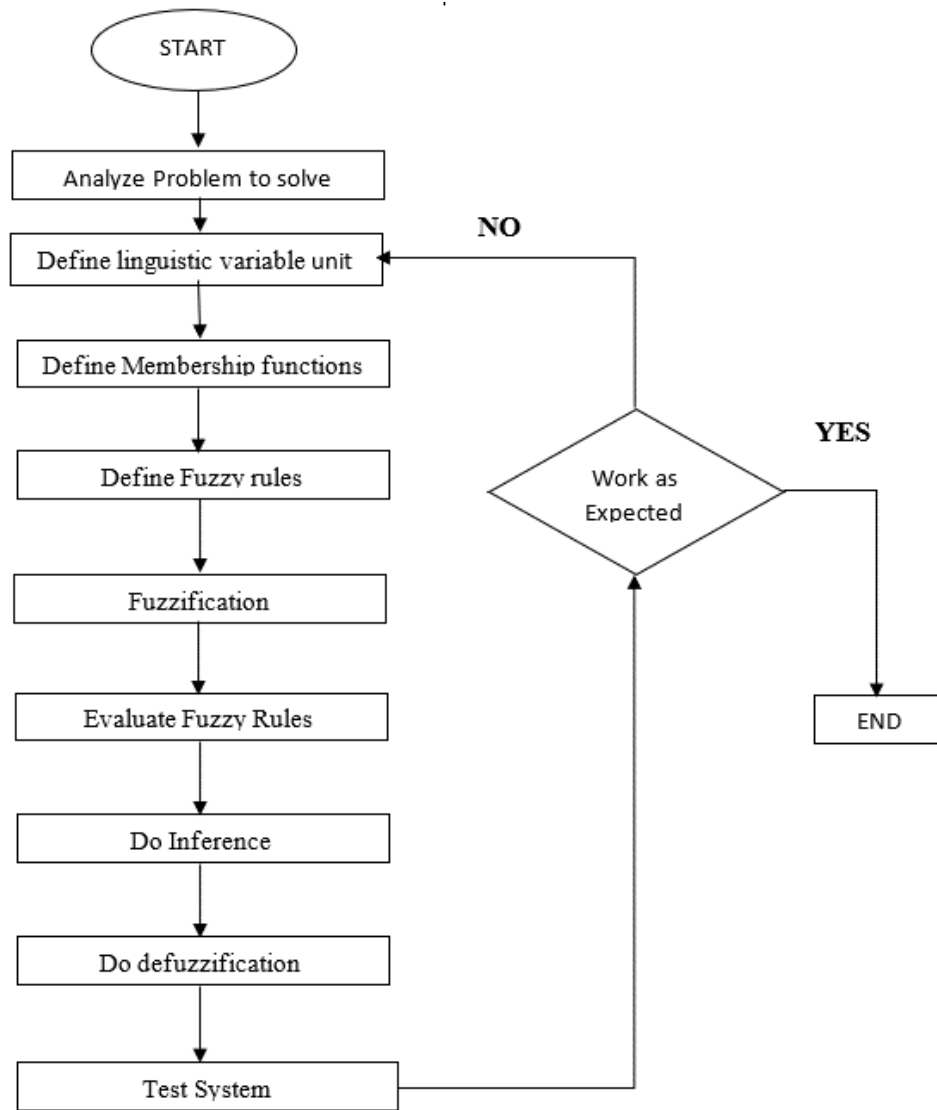


Figure 3: Flowchart of the control process

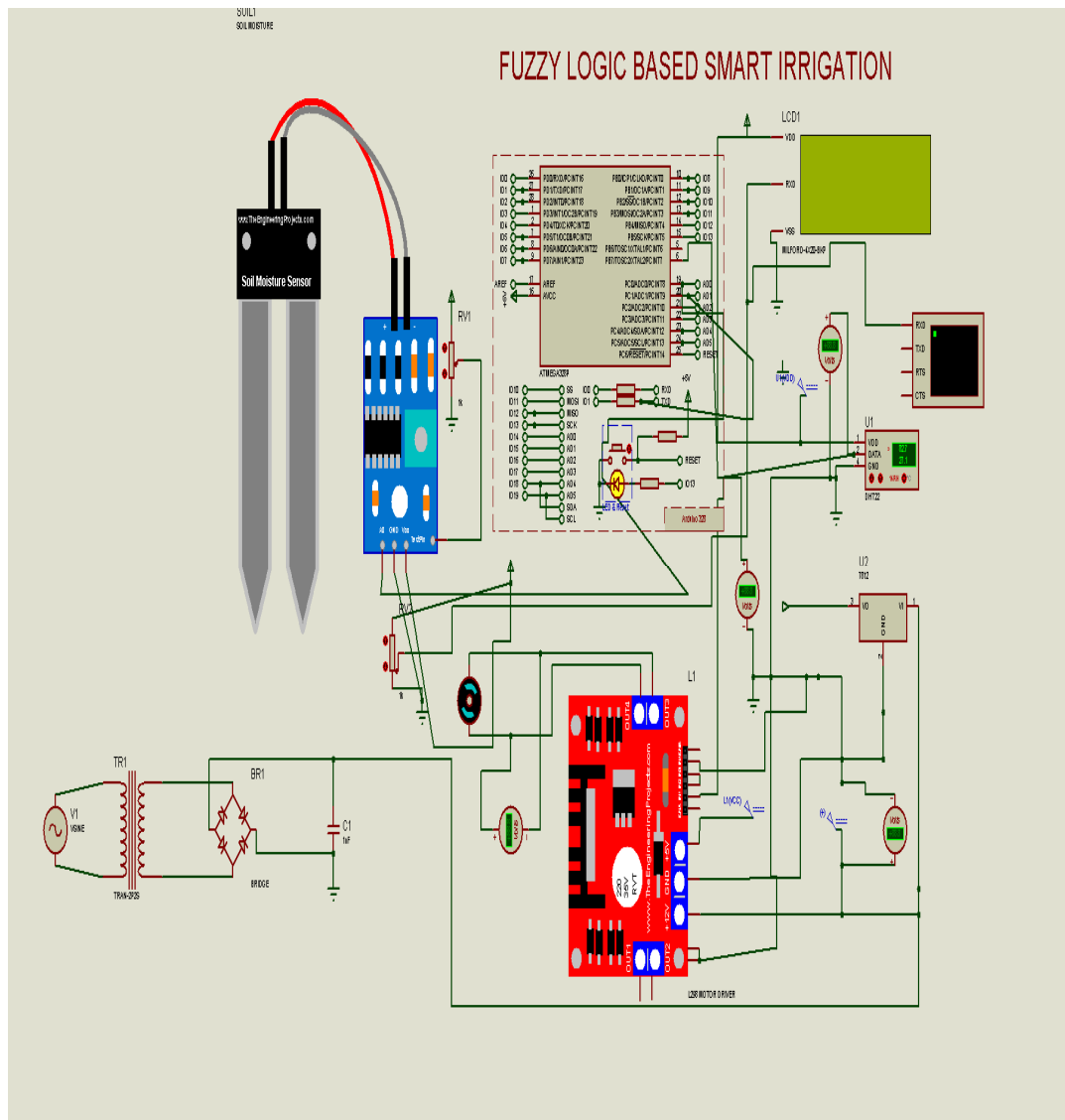


Figure 4: Circuit diagram for the automatic irrigation system using fuzzy logic

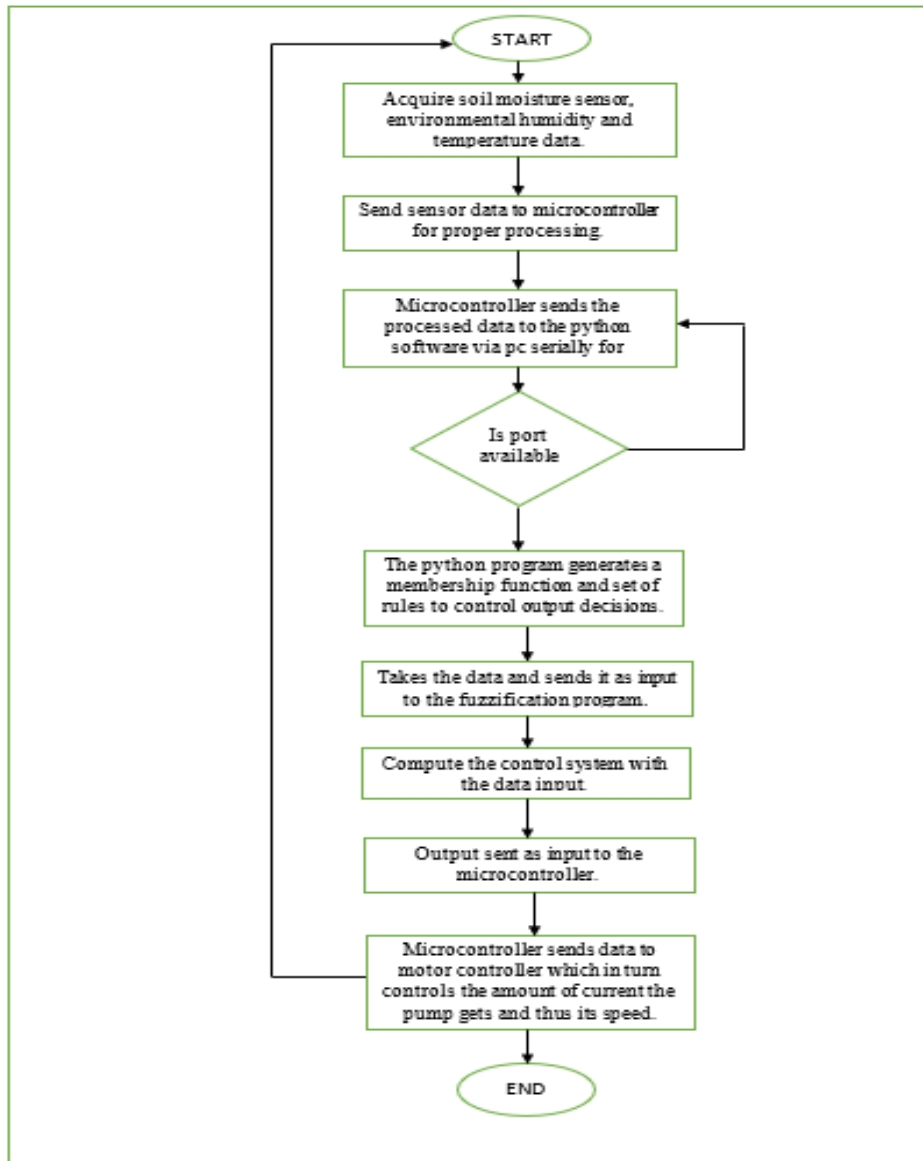


Figure 4: Flowchart of the program design.

The simulation of the system was done using Proteus 8 professional electronic workbench, due to its simplicity when simulating and its vast collection of electronic components, both analogue and digital. The simulation aims to

have an overview of problems that may occur during hardware implementation. Figure 5 shows the circuit diagram on the Proteus 8 professional design suite environment.

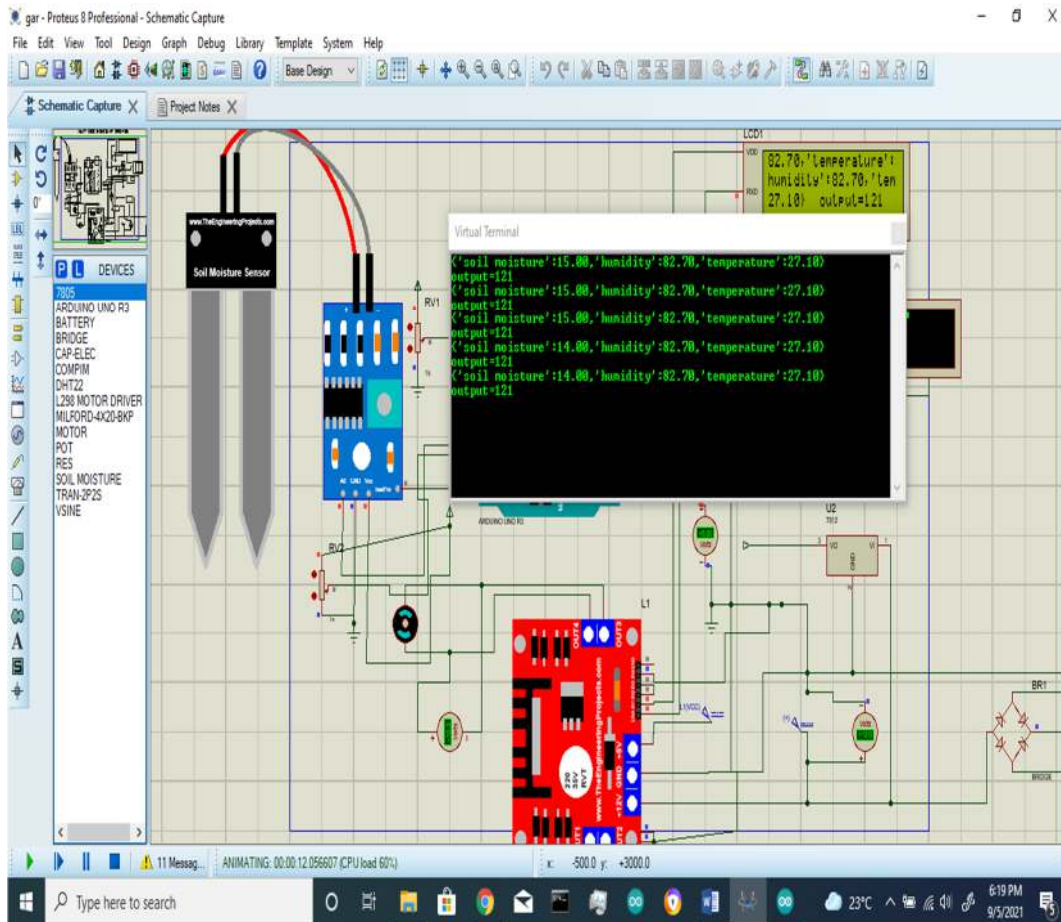


Figure 5: Diagram of Proteus 8 professional electronic workbench

For the proteus simulation, data were gotten from the soil moisture, humidity and temperature sensor and displayed on a virtual terminal. The output from our fuzzy logic was indicated with a potentiometer which was connected to the analogue pin of the sensor. A voltmeter was connected to the pump motor to measure the amount of voltage supplied to the motor pump. This variation of the output with the potentiometer was seen to cause a change in the voltage sent to the motor via the enable pin of the motor driver which then cause a speed variation of the pump motor to the output obtained. The output from the simulation was slightly different from the real-life results but was in line with the fuzzy logic controller rules.

RESULTS AND DISCUSSION

The results after the simulation in Proteus were presented in Table 2. The Automatic fuzzy logic-based irrigation system was tested with input values from atmospheric temperature, humidity and soil moisture sensors by sending the data gotten from these sensors to the controller which then passes the data to the microcontroller unit. The controller unit then sends the data serially to the computer python program which runs the fuzzy logic algorithm and the output is sent back to the microcontroller unit which is used to control the speed of our pump to the data sent from the sensors. The membership function of temperature, humidity, soil moisture and pump speed are presented in Figures 6 – 9, with Table 3, showing the fuzzy logic rules.

Table 2: Table of results after simulation

S/N	INPUTS			OUTPUT
	HUMIDITY (RH)	TEMPERATURE (°C)	SOIL MOISTURE (%)	PUMP SPEED (%)
1.	82.7	27.1	15	121.0
2.	82.3	26.5	19	121.3
3.	82.1	26.1	22	121.7
4.	82.5	26.9	18	120.9

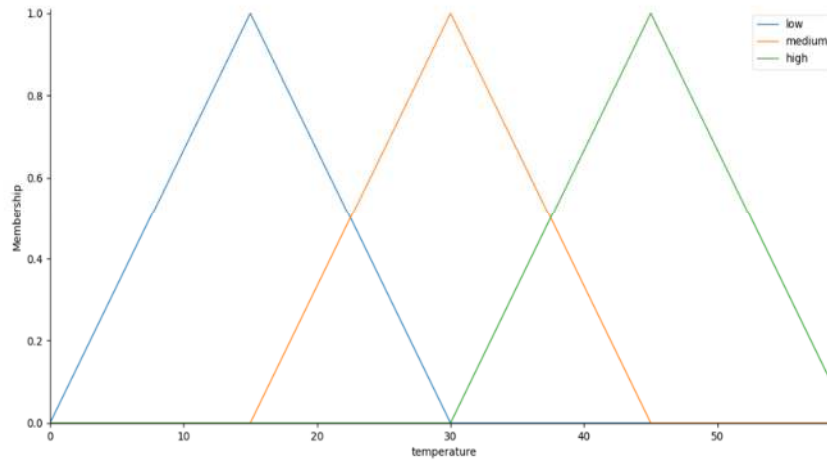


Figure 6: Temperature membership function

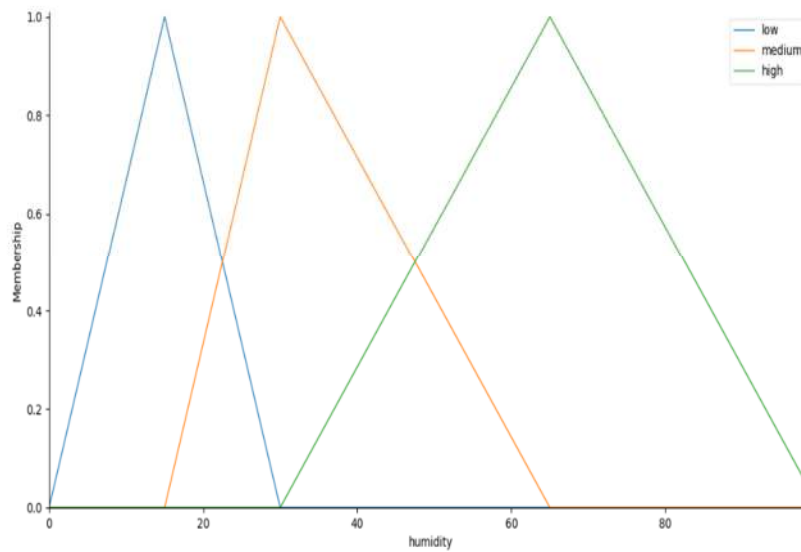


Figure 7: Humidity Membership function

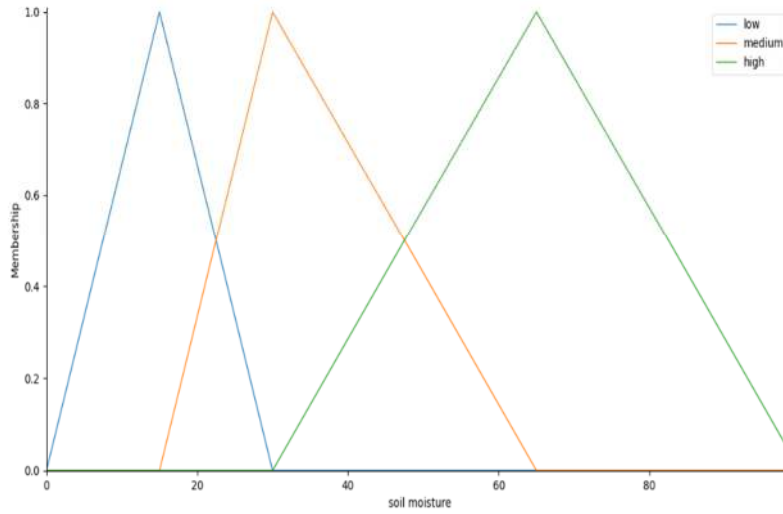


Figure 8: Soil Moisture Membership function

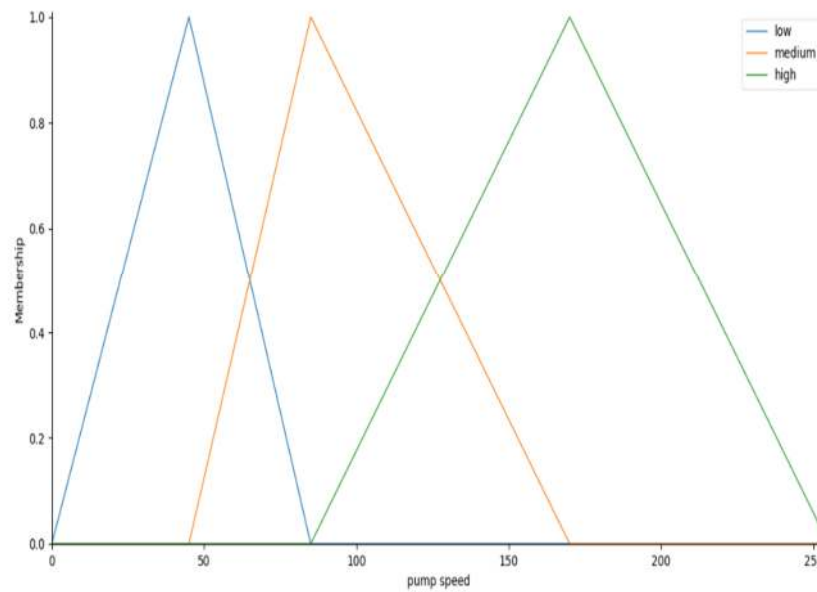


Figure 9: Pump speed membership function



Table 3: Table showing the fuzzy logic rules

S/N	INPUTS			OUTPUT
	HUMIDITY	TEMPERATURE	SOIL MOISTURE	PUMP SPEED
1.	HIGH	HIGH	LOW	HIGH
2.	HIGH	HIGH	MEDIUM	MEDIUM
3.	HIGH	HIGH	HIGH	HIGH
4.	HIGH	LOW	HIGH	MEDIUM
5.	HIGH	MEDIUM	HIGH	LOW
6.	LOW	HIGH	HIGH	MEDIUM
7.	MEDIUM	HIGH	HIGH	LOW
8.	MEDIUM	MEDIUM	MEDIUM	LOW
9.	LOW	LOW	LOW	HIGH
10.	HIGH	MEDIUM	MEDIUM	LOW
11.	MEDIUM	HIGH	MEDIUM	MEDIUM
12.	MEDIUM	MEDIUM	HIGH	LOW
13.	HIGH	LOW	LOW	MEDIUM
14.	LOW	HIGH	LOW	HIGH
15.	LOW	LOW	HIGH	LOW
16.	HIGH	MEDIUM	LOW	HIGH
17.	HIGH	LOW	MEDIUM	LOW
18.	LOW	MEDIUM	HIGH	LOW
19.	MEDIUM	LOW	HIGH	MEDIUM
20.	LOW	HIGH	MEDIUM	MEDIUM
21.	MEDIUM	HIGH	LOW	HIGH

A PC console software was developed using python which aided the fuzzy logic. The

results obtained for the rules in Table 3 were shown in Table 4.

Table 4: Table of results after testing

S/N	INPUTS			OUTPUT
	HUMIDITY (RH)	TEMPERATURE (°C)	SOIL MOISTURE (%)	PUMP SPEED (%)
1.	74	29.4	1	127.0
2.	73	29.6	2	126.8
3.	73	29.6	28	121.0
4.	74	29.5	29	120.7
5.	73	29.4	30	120.7
6.	73	29.4	20	122.2
7.	73	29.4	19	121.7
8.	74	29.6	31	120.8
9.	73	29.6	32	120.6
10.	74	29.6	34	121.0

An operational test was done to observe how the system responded to input values from sensors (soil moisture, humidity and temperature sensors), using the fuzzy logic operation. The test was done for two conditions:

1. State of the system when powered; when powered, the LCD comes on and smart irrigation is being displayed on the LCD from the code burned into the microcontroller.

2. State of the system when receiving input from the sensors; the system compares the data input from the sensors and responds under the fuzzy rule that matches the values to generate an output that is displayed on the LCD as explained in the process unit flowchart in Figure 4.

The results in Figure 10 were obtained after carrying out the physical test and simulation. The result contains the data gotten from our monitoring sensors which were sent into the python software developed and used to obtain the output from our fuzzy logic algorithm which is used to control the state of the motor speed. It is seen that different input data from the sensors, gave different output values which determine the speed of our motor.

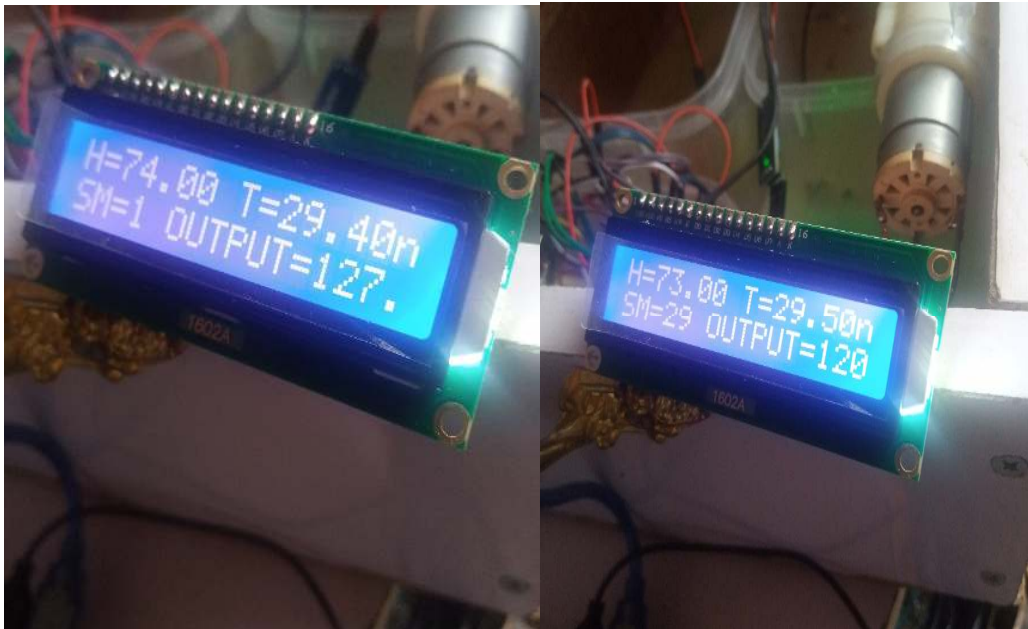


Figure 10: LCD of the results obtained during testing

CONCLUSION

In this study, an automatic irrigation system with DHT22 and soil moisture sensor using fuzzy logic was designed, implemented with Arduino UNO ATmega 328p microcontroller and tested. Proteus was used to simulate the system with three inputs; soil moisture content, temperature and humidity and one output which the pump speed is. The use of fuzzy logic was to make the irrigation process act as though it has the reasoning of the human mind and uses this reasoning or intuition to control the rate at which water is supplied to the field. A proper understanding of how the input and output parameter relates to one another was sufficient to

design the system to perform according to specifications.

REFERENCES

- Abdullah, N., Durani, N. A. B., Shari, M. F. B., Siong, K. S., Hau, V. K. W., Siong, W. N., and Ahmad, I. K. A. (2020). Towards smart agriculture monitoring using fuzzy systems. *IEEE Access*, 9, 4097-4111.
- Adelodun, B., and Choi, K. S. (2018). A review of the evaluation of irrigation practice in Nigeria: Past, present and future prospects. *African Journal of Agricultural Research*, 13(40), 2087-2097.



- Agrawal, N., and Singhal, S. (2015). Smart drip irrigation system using raspberry pi and arduino. In *International Conference on Computing, Communication & Automation* pp. 928-932.
- Dharrao, D., Kolape, L., Pawar, S., and Patange, A. (2015). Automated irrigation system using WSN. *Asian Journal of Engineering and Technology Innovation*, 3(6), 18-21.
- Ejofodomi O.A., Ofualagba G., Ighrakpata, U., Chouikha, M. (2018) Automation of irrigation systems and design of automated irrigation systems, *International Journal Water Resources Management and Irrigation Engineering Research*, 2(1) pp.11-27.
- Jaichandran, R., Irudhayaraj, A. A., Surabhi, R. K., and Sinha, T. (2013). Prototype for automatic controlling and remote accessing of irrigation motor. *International Journal of Innovative Research in Computer and Communication Engineering*, 1(4), 800-807.
- Jain, R., Kulkarni, S., Shaikh, A., and Sood, A. (2016). Automatic irrigation system for agriculture field using wireless sensor network (WSN). *International Research Journal of Engineering and Technology (IRJET)*, 3(04), 1602-1605.
- Khan, F., Shabbir, F., and Tahir, Z. (2014). A fuzzy approach for water security in irrigation system using wireless sensor network. *Science International*, 26(3).
- Reshma, S., and Babu, B. S. M. (2016). Internet of things Based Automatic Irrigation System using Wireless Sensor Networks. *International Journal and Magazine of Engineering, Technology, Management and Research*, 3.
- Sudha, M. N., Valarmathi, M. L., and Babu, A. S. (2011). Energy efficient data transmission in automatic irrigation system using wireless sensor networks. *Computers and Electronics in Agriculture*, 78(2), 215-221.
- Touati, F., Al-Hitmi, M., and Benhmed, K. (2012). A fuzzy logic-based irrigation management system in arid regions applied to the state of Qatar. *WIT Trans Ecol Environ*, 168, 189-199.