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Development of an Internet of Things Based Irrigation System for an Improved Farming Technology

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ABSTRACT: Plants need water supply regularly for survival, production and proper growth. This is the reason behind all forms of irrigation practices, from manual supply of water to the root of plants, to the use of pumping machines and power generators to irrigate farmlands. This article presents a system that uses Internet of Things approach to monitor the irrigation system while controlling it automatically using microcontroller based system. This is useful for farmers, especially in an improved farming technology where buckets, bags, sacks and other household containers are used as farm lands where the soil is poured for plants to grow on. The system was implemented using six batteries connected in parallel to a power bank module as the source of power. It also consists of an Arduino board which is based on ATmega328P microcontroller, a water level sensor to monitor the availability of water in the water tank, and soil moisture sensor to detect the existence of water in the enhanced soil. When the soil moisture sensor collects the data of the level of moisture of the soil, it sends it to the microcontroller. If the soil moisture is low, the microcontroller integrates the pump to turn on and wet the soil. On the contrary, if the soil moisture level is high, the pump will be turned off. These information are sent to the cloud through the wifi module while the registered farmer receives updates on their mobile device. The device was tested on different dry soil types and it moisturized them correctly sending the appropriate signals to various outputs. The results showed an efficiency of above 75% and a reliability of above 75%. This device is recommended for use in all enhanced farmlands especially in developing nations and regions with extreme weather conditions to yield better agricultural produce.

KEYWORDS: Arduino uno, IOT, Irrigation, Soil moisture sensor and Thingspeak.

I. INTRODUCTION

Water is a factor in the physical, chemical and biological phenomena in the soil. It provides sustainability not only for living beings but also for the soil. Water entry into the soil, movement and amount of control, is vital in determining soil fertility. Water is essential and very important in agricultural processes. Without water, plants growth and development are hindered or affected negatively, but presently, the current change in weather and climatic condition has resulted in increase in amount of sunlight which has led to increase in the dryness of the soil. During this period, most plants, including vegetable plants are unable to withstand the lack of enough water in the soil which definitely affects their survival. All they need is water, and the solution to this is irrigation, although local farmers always find it difficult to irrigate their plants, mostly when it is a large farmland. Moving from one plant to another and wetting them is not an easy task, with the help of an automatic irrigation system, they are being relieved of the stress. This design is very useful for farmers and individuals at home.

II. THE IMPROVED FARMING TECHNOLOGY

It is noteworthy that all plants need adequate water supply for their proper growth and development. In other words, plants should not suffer from lack of adequate water supply, because this could hinder their proper growth. So, without water, plants cannot survive easily. Some may even die as a result of lack of adequate water supply. That is why rainfall is essential for the proper growth of plants. Most farmers find it challenging to ensure that enough water is supplied to their farmland. As cost of acquiring a land and the extra cost of clearing and preparation are other critical needs for farmers. Therefore, people employed the modern technology of improved farming system such as the use of buckets, clothing materials, bags, sacks, and other containers as farmlands. This is referred to as the improved or enhanced farming technology. Also, plants are confirmed to improve the indoor climate and they also have psychological benefits in workplaces. However, rainfall does not irrigate indoor plants and it is not easy for farmers to take care of their plants regularly. Since people do not irrigate these plants when they go on vacations or as a result of engagements, there is a chance that the plants may suffer water loss. This could result into low production, reduction in profits, stunted growth or death of plants.

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III. THE IOT BASED SYSTEM

IOT is an acronym for Internet of Things and it simply means the interconnectivity of devices such as objects, materials, gadgets, and so on to send and receive data through the use of sensors, internet and other technologies without human intervention.

This article presents an IOT based irrigation system for an improved farming technology and the following specific objectives were achieved in the feat:

I design of an IOT based irrigation system using water level sensor and soil moisture level sensor;
ii construction of a microcontroller based automatic irrigation system;
iii integration of the system with the cloud and mobile technology using wifi module and GSM module;
iv testing the IOT based irrigation system; and
v evaluating its performance.

This system is suitable for irrigating plants and accessing the soil and plant condition through IOT, because the soil moisture sensor is capable of determining the level of humidity in the soil. This is displayed on the LCD screen. The soil moisture sensor senses that the humidity of the soil is low and a signal is sent to the microcontroller to release water from the pump to the soil. The water sensor displays the level of water available in the container on the LCD screen and on the user's phone through IOT.

IV. LITERATURE REVIEW

The automatic irrigation system has been developed in different way using different systems. Generally, most of the researchers used soil moisture sensors to detect the level of humidity of the soil. Using Arduino board they developed systems that received signal from the sensor to turn on the pump for the irrigation process to begin or stop. Most of the researchers used the main electricity regulated power supply to power the system, but with the use of step down transformer they reduced the voltage to the needed voltage, some at laboratory level used battery to power their circuit, while some used the power generated from the sun. Most researchers develop theirs in such a way that it can be used on farmland.

The Processing Unit of existing irrigation systems

The system designed by [1], used an arduino board which acts as the brain that controls all the input and output devices. It uses Fuzzy rule base, which is a database of rules and each rule is formed by "IF-THEN". The IF part is conditional given information and in the THEN part is the action of the system. [2] used a different method by employing the use of 8051 micro-controller to control and co-ordinate the entire process of irrigation. The main difference between the system designed by [1] and the one designed by [2] is that [2] used a Bluetooth device; when the Microcontroller switched off the motor using the relay driver; it sends an alert message through the Bluetooth as "Water Level Low". Humidity sensors detect the relative humidity of the immediate environments in which they are placed and when it is likely to rain, the sensor reads a high value which leads to tripping of the motor when moisture is low in soil by the Arduino. This is indicated to the farmers by sending a message that "Humidity occurred" and the Motor can be off by sending through the Bluetooth. [7] also used Bluetooth module in designing their systems, but they used a Bluetooth module HC-05 and connected it to the Arduino board, it was connected to a smartphone, the online MIT App inventor was used to create an app which was installed on the smartphone. The system by [3] used the SIM900 GSM Shield which is an ultra-compact and wireless module. The GSM Shield connects to Arduino boards to send and receive the SMS to/from home owner mobile using GSM library. Another feature of the system designed by [2] is that the authors used 16 x 2 LCD to display the condition of the soil. [14] used a prototype that monitors the amount of soil moisture and temperature. A predefined range of soil moisture and temperature was set and varied with soil or crop type. In case the moisture or temperature of the soil deviates from the specified range, the watering system will be turned on/off. [29] applied the Lora Technology in which sensor Nodes collects the data of soil moisture, temperature and humidity. For the automatic irrigation system by [11], according to the input received by the microcontroller, it keeps a continuous process and activate the pump when necessary. The system by [26] used the Artificial Neural Network (ANN) based intelligent control system for effective irrigation scheduling. The study by [9] involved the use of humidity sensor and soil moisture sensors to sense the change in temperature and humidity and give an interrupt signal to the micro-controller and thus the motor is activated. In the case of [13], the sensors were connected to the arduino, the microcontroller received the data and the AC motor is controlled by the microcontroller. The humidity sensor used by [12] was used to detect the level of humid in the air, then the value will be sent to the microcontroller, which will then compare with the value gotten from the soil moisture sensor, and then determine the amount of water to be supplied to the soil through the water pump. This components were connected to the arduino board which contains the ATmega328 microcontroller, which in turn controls the system. In the study by [15], each node of WSN mainly consists of memory, processor and an RF transceiver. The coordinator node is based on Raspberry Pi (Rpi) embedded. Linux board and End device is based on Arduino UNO Atmega328 platform. Researcher [26] based their system on artificial Neural Network (ANN) based intelligent control system for effective irrigation scheduling, while [21] used the Zigbee technology which wirelessly transmit values of soil moisture and temperature from field to substation which controls the state of the motor.

The Power supply Unit of the existing irrigation systems

The required power of 5v is given by a supply circuit that contains a transformer, bridge rectifier circuit and a voltage regulator for the system by author [2] but [6] used a PV module which is used has an output voltage of 12V DC capable of supplying a direct current of 300mA which is enough to switch on the pump. The power unit of the system by [6] also consists of Solar panel, 12v Relay, Voltage regulator 7805 and 7812. The system developed by [10] used main power supply. The authors of [4] powered their device using photovoltaic system.

The sensors Used by the existing irrigation systems

The system designed by [1] used FC-28 soil moisture sensor which act as the input device. This sensor needed a soil as an input activator. The system is tested for dry, moistened and soggy soil. [2] used a different method by employing the use of a soil moisture sensor through which the soil moisture content is measured by using two metallic rods. The system designed by [3] also added a rain sensor which gives the alarm when there is rain, so the homeowner can stop the irrigation. The system designed by [5] was designed to continuously sense the moisture level of the soil. The system responds appropriately by watering the soil with the exact required amount of water and then shuts down the water supply when the required level of soil moisture is achieved. Study [14] used a prototype that monitors the amount of soil moisture and temperature. The working of the moisture sensor is simple and straight forward. The moisture sensor just senses the moisture of the soil. The change in moisture is proportional to the amount of current flowing through the soil. In the system by [9] humidity sensor and soil moisture sensors sense the change in temperature and humidity and give an interrupt signal to the micro-controller and thus the motor is activated. The automatic irrigation by [11] used sensor that senses the current values and sends the data to data acquisition system. For the project by [10], the sensors acquire data, and the obtained data determine the performance of the system while the electronic valve is controlled by an Arduino. Also the system by [30] consists of solar powered water pump along with an automatic water flow control using a moisture sensor.

The Output Unit of the existing systems

The system designed by [1] has an output device like a liquid crystal display (LCD), buzzer, light-emitting diode, and water pump. For [14], in case of dry soil and high soil temperature, it will activate the irrigation system, pumping water for watering the plants. The water pump and the servo motor are coupled with the output pins. If the sensors depart from the predefined range, the controller turns on the pump. The servo motor is

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used to control the angular position of the pipe, which ensures equal distribution of water to the soil. A LED indicator indicates the status of the pump. The system by [8] shows that if the moisture content in the field gets reduced to lower threshold limit, the signal is produced from the microcontroller to turn on relay. The relay in turn opens the solenoid valve then water from the source is supplied to the field. The output unit of [25] consists of 16×4 LCD which is connected to the microcontroller, which displays the soil moistures level and switches are provided to set the limits of humidity for switching the individual solenoid valves controlling the water flow to the field. [21] used Zigbee technology; wirelessly transmit values of soil moisture and temperature from field to substation which controls the state of the motor.

The Proposed System

As presented in the above literature review section, many research studies have focused on developing an automatic irrigation system that automatically senses the level of moisture present in the soil which triggers the microcontroller to automatically wet the soil. However, most of the studies have not examined how the automatic irrigation system data can be accessed via an android phone and through the cloud. In this report, the automatic irrigation system has been upgraded into an IOT (Internet of Things) based system that constantly uploads the system data which includes the condition of the soil, the motor and the water in the container(s). The use of a GSM module was also employed which allows the user to check the condition of the soil, the motor and the water in the container via a phone. From the reviewed works above, most system were powered by main regulated power supply, others powered theirs with a computer system for testing purposes. However, this work has employed the design of a rechargeable power bank, which can be charged at any time and in turn will continue to power the system even when there is no power from the main power supply.

More so, most of the reviewed works can be used on farmland whereas this design is suitable for an enhanced or improved farming technology, such as bag and bucket farming systems in homes, houses and offices. Also the use of a water level sensor was employed to monitor the level of the water in the container. The state of the soil moisture is also displayed on a LCD screen.

V. METHODOLOGY

Components and Equipment Required

The components and equipment required for the design of the IOT based irrigation system are:

Lithium batteries, Arduino UNO, Soil Moisture Sensor, ESP8266 Wi-Fi module, GSM Module, Arduino Software (IDE), Relay Module, 5v D.C Water Pump, Water Level Sensor, Liquid Crystal Display (LCD).

System Design

Six Li-ion batteries connected in parallel form the power source of the system. The lithium batteries were connected to a power module which steps up the 3.7volts produced by the batteries to 5.0volts needed by the Arduino Uno board. The batteries were connected in parallel and connected to the power module to supply 5volts at the output. The batteries are being charged by main power supply through the port on the power module. The arduino uno contains ATMega 328P microcontroller which serves as the brain of the system. It controls the operation of the system by receiving signal sent from the input devices (water level sensor and soil moisture sensor) and processes it to display the output values on the LCD screen and turn on the 5v D.C pump when the soil is dry.

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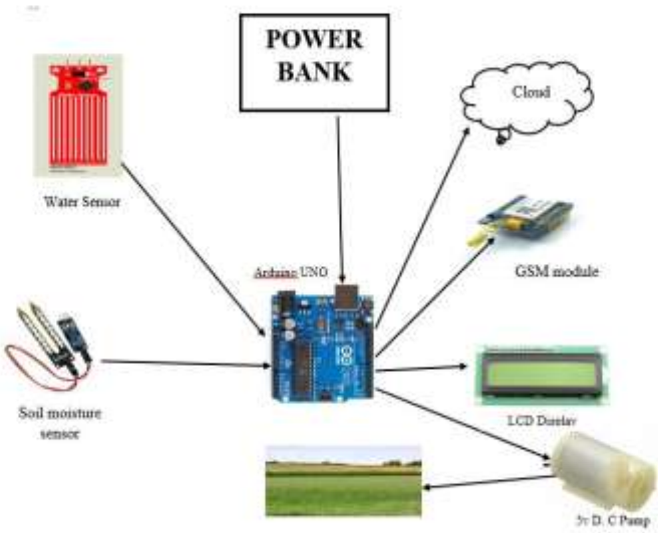

Figure 1: System Design of IOT based irrigation system

Functional Block Diagram of the System

This system is made up of both the hardware part and the software. As indicated in Figure 2, the hardware consists of the input, the processing unit, the power supply unit and the output unit. The input system is made up of components such as: the soil moisture sensor and the water level sensor; the processing unit is the Atmega328P microcontroller, the power supply unit is made up of li-ion batteries; while the output unit consists of the LCD, Wi-Fi module, GSM module, the cloud and the 5v water pump.

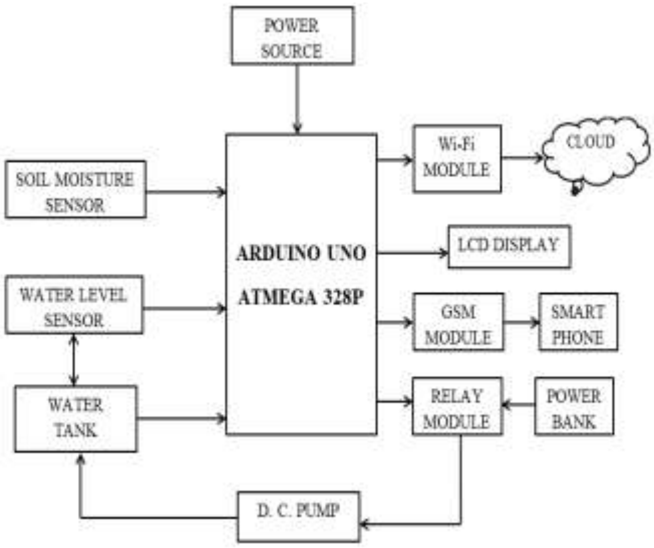

Figure 2: Block Diagram of the irrigation system

Design of the Complete System Circuit

The level of humidity of the soil or percentage of moisture present in the soil must be detected and known. This will help the system to determine if it has to wet the soil or not. The level of moisture present in the soil will be detected through the use of soil moisture sensor. This sensor has two probes which are placed into the soil and connected to the Arduino board. These probes will measure the level of moisture present in the soil. In the program that will control the system, two thresholds are set, such that if the humidity of the soil is less or lower than the minimum threshold, then the sensor will send the information to the processing unit of the system to start or open the pump. But if the humidity of the soil is higher than the preset maximum threshold, the sensor will send the information to the processing unit to stop or close the pump. The sensor contains three pins. The VCC pin was connected to a power terminal which receives 5volts and serves as the power pin which turn the sensor on immediately it receives power. The GND pin was connected to a ground terminal while the A0 pin was connected to the A0 pin on the Arduino board.

The soil moisture sensor is the part of the system that measures the level of water in the container. The water level sensor was connected to the Arduino board. When the water in the container is too low, the information will be sent to the board. As shown in the circuit, the power pin "+" was connected to a power terminal which supply 5volts to the sensor through the pin, while the negative pin "-" was connected to a ground terminal which supplies "0" volts to the pin. For the water level to be measured the pin "S" was connected to the analog pin "A3" on the Arduino board, this will send the data received from the sensor to the Arduino board.

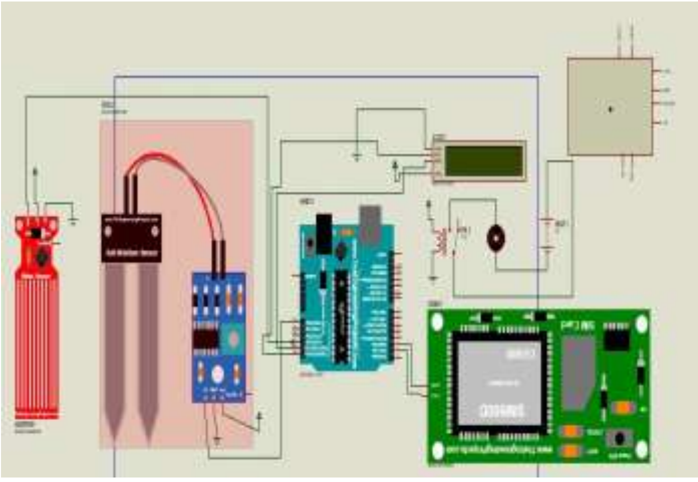

Figure 3:Simulation of the irrigation system circuit

Hardware setup of the complete system

This system is designed and constructed to automatically carry out irrigation. For this to be possible, different units consisting of different devices are set up to work together to carry out this operation. As shown in Figure 3, a water level sensor is connected to the board which is then inserted into the container or reservoir, which informs the microcontroller if the water is low or full. A soil moisture sensor is connected to the Arduino board, the sensor senses the level of humidity in the soil and send it to the microcontroller for the microcontroller to trigger the pump connected to it to start wetting when the soil humidity is low and to stop or off the pump when the humidity of the soil has reached the stipulated threshold. The LCD was connected to the microcontroller, the LCD receives the signal from the controller to display the level of water in the reservoir and the level of moisture in the soil

For the irrigation process to occur the Arduino uno board was used as the processing circuit. The microcontroller on the board accepts or receives data from the components connected to it through its input pins, components such as soil moisture sensor and water level sensor. The microcontroller after processing the data received from the input devices will send instruction to the output devices. It will send the information to be displayed to the LCD, it will instruct the pump to open or start pumping if the humidity in the soil is low while it will instruct it to stop if the humidity is high. The system will continue to water the soil until the moisture of the soil reaches the stipulated threshold, after which it turned off the pump.

Software setup of the system

The ThingSpeak IOT software platform was adopted for cloud-based remote monitoring. The software is presented through the method of solution indicated as Algorithm I:

Algorithm I

Start

Step 1: Set k_alpha; K-alpha is constant for soil moisture

level in container

Step 2: Set k_beta;K_beta is constant for water

level in tank

Step 3: Read alpha; alpha is soil moisture level in Container

Step 4: Read beta; beta is water level in tank

Step 5: If beta < k_beta Then

Step 6: Send data to LCD, phone & cloud

Step 7: Else

Step 8: If alpha < k_alpha Then

Step 9: Send Sms to farmer

Step 10: Update Cloud data on Thingspeak
Step 11: While(alpha < k_alpha)
Step 12: Put on Water Pump
Step 13: Auto irrigation begins & continues
Step 14: display updated data on LCD
Step 15: End if
Step 16: End if
Step 17: Send updated information to phone & cloud
Step 18: Stop

VI. RESULTS

Functionality Testing

Table 1 describes the testing activities carried for the water level sensor. It starts with turning the system on, after which the water sensor was dipped into the water container filled with water. The water was consistently reduced which resulted in change of the output or result given by the LCD.

TABLE I: TESTING OF WATER LEVEL SENSOR

No.	Water Level Testing Activities
1	The Arduino was connected to the power supply designed for the system.
2	The water level sensor was inserted into the water container.
3	The results displayed on the LCD and through the Bluetooth module were tabulated and recorded.

Result

When the system was turned on, the water level sensor was inserted into the water container. Since the system was set to two thresholds, when the water container was filled up, the water level sensor detects that the water container is filled up to the upper threshold. When the water reduces and is lower than the upper threshold set in the program but is not as low as the lower threshold the sensor triggers the LCD to display "Water level: Mid" and when the water reduces to the lower threshold set the sensor senses it and the LCD displays "Water Level: Low".

The water level sensor was able to detect when the water is low, in the middle state, or full and the output was displayed on the LCD screen as shown in Figure 4.

Figure 4: LCD displaying the level of water in the container

TABLE 2 TESTING OF SOIL MOISTURE SENSOR AND THE PUMP

No.	Soil Moisture Level Testing Activities
1	The Arduino was connected to the power supply designed for the system.
2	20 samples of dry loamy soil, clay soil and sandy soil were provided
3	The moisture sensor was dipped into each of the soil.
4	The results displayed on the LCD were tabulated and recorded.

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According to Table 2, to test the efficiency, reliability and accuracy of the soil moisture sensor, twenty samples of soil were presented. The time of irrigation process was recorded, starting from when the soil moisture sensor was inserted to the soil to when the LCD displayed the percentage of moist soil. Table 3 and 4 show the test and the recorded results.

Efficiency Test

The system was put into test by placing it beside a vegetable plant, the plant has survived for over a week by manual irrigation after which the automatic irrigation was used, the same vegetable plants are shown in Figure 5 where the plants has survived and developed after eight days with the help of the automatic irrigation system. Therefore the water supplied by the IOT based irrigation system was able to sustain the plant in the enhanced farm and was able to keep it alive and healthy.

Figure 5: A plant after a week of undergoing automatic irrigation

TABLE 3: THE FIRST RESULTS OBTAINED FROM OPERATIONAL TEST OF THE SYSTEM

Soil Type	Initial soil state	Initial soil state(%)	Irrigation time, pump off (seconds)	Final Soil State	Final Soil State(%)	Expected Soil State(%)
Sandy	Dry	0	14	Moist	59	40
Sandy	Dry	1	13	Moist	61	40
Sandy	Dry	1	14	Moist	59	40
Clay	Dry	1	20	Moist	72	40
Clay	Dry	0	19	Moist	71	40
Clay	Dry	0	19	Moist	73	40
Loamy	Dry	1	16	Moist	65	40
Loam	Dry	2	17	Moist	70	40

y						
Lo am y	Dr y	2	15	Moi st	71	40
Lo am y	Dr y	1	16	Moi st	69	40

TABLE 4: THE SECOND RESULTS OBTAINED FROM OPERATIONAL TEST OF THE SYSTEM

Soil Type	Initial soil state	Initial soil state (%)	Irrigation time, pump off (seconds)	Final Soil State	Final Soil State(%)	Expected Soil State(%)
Sandy	Dry	0	13	Moist	61	40
Sandy	Dry	1	13	Moist	59	40
Sandy	Dry	1	14	Moist	59	40
Clay	Dry	0	19	Moist	73	40
Clay	Dry	0	18	Moist	71	40
Clay	Dry	1	19	Moist	74	40
Loamy	Dry	2	17	Moist	70	40
Loamy	Dry	1	17	Moist	69	40
Loamy	Dry	1	15	Moist	70	40
Loamy	Dry	2	16	Moist	71	40

Reliability Test
Table 5 indicates the result of the reliability test on loamy soil.

TABLE 5: RELIABILITY TEST FOR LOAMY SOIL

N/O	**Result 1**	**Result 2**	**Agreement**
1	16	17	0
2	17	17	1
3	15	15	1
4	16	16	1
			3/4

Percentage reliability = no of results in agreement / total number of results
%R = 3/4 x 100
%R = 0.75 x 100
%R = 75%
Percentage reliability of the system for Loamy soil = 75%

Accuracy Test
Using the results in Table 3 and 4, the formula for percent accuracy is;
Percent accuracy = ((Final Soil State - Expected Soil State) / Expected Soil State) x 100
%A = ((Fs – Es) / Es) x 100
Since Loamy soil is the best soil for agriculture, random final soil state of 70% was chosen
%A = (70 – 40 / 40) x 100
%A = (30/40) x 100
%A = 0.75 x 100
%A = 75%
Percent accuracy = 75%

VII. DISCUSSION OF RESULTS

It can be seen from the results obtained from the test that the system responded linearly with respect to the water requirement of the three soil types. There is a linear relationship between the degree of soil dryness and the time taken to irrigate the soil. From Table 3; for sandy soil; the system changed from "DRY SOIL" to "MOIST SOIL" after 14, 13 and 14 seconds respectively, for the clay soil samples to become wet, the time spent was 20, 19 and 19 seconds respectively, while at dryness state, irrigation durations for loamy soil were 16, 17, 15 and 16 seconds. It is seen that irrigation in clay soil took the longest duration among the three soil samples, while loamy soil took longer duration than sandy soil.

The percentage reliability of the system for loamy soil is 75%, which showed that the system is reliable to be used for indoor plants or other improved farming technology. The system used an average of 16 seconds to wet or irrigate the plant until the water reaches or passes the stipulated threshold, and the system continues to monitor the plant in order to start the irrigation process again immediately the water in the soil is confirmed to be below 40%. The percentage accuracy of the system for loamy soil is 75%, therefore the system responded accurately by giving the accurate water supply to the plant and measuring the moisture level of the soil accurately.

VIII. CONCLUSIONS

This system will promote proper irrigation system, which can be used in homes, shops, houses, and offices for the enhanced or improved farming technologies. The percentage reliability of the system for loamy soil is 75%, which showed that the system is reliable to be used for indoor plants or other improved farming technology. The percentage accuracy of the system for loamy soil is 75%, therefore, the system responded accurately by giving the accurate water supply to the plant and measuring the moisture level of the soil accurately. The system is also efficient since it is capable of keeping plants alive by monitoring the level of moisture in the soil and irrigating the plant when needed. Using the esp 8266 Wi-Fi module, the system data are stored or saved online on the ThingSpeak platform, and the GSM module helps to transfer the data from the system to the smartphone. Researchers can make use of the IOT based data saved in the cloud for researchers into plant related matters and predictions on plant growth rate. This device is recommended for use in all enhanced farmlands especially in developing nations and regions with extreme weather conditions to yield better agricultural produce.

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