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PRACTICAL APPROACH: IOT BASED CROP IRRIGATION MANAGEMENT SYSTEM

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Abstract
Agricultural yield is an essential part of any country's economy. More so for Pakistan, where over 70% of the population is connected to a farming-based economy, while 25% of the nation's GDP derives from farming-based activities, playing a crucial role in the country's growth. Various issues related to the field of agriculture continually hamper such growth; lack of real-time monitoring and management of crops is one of them. An inevitable solution to such problems is to opt for modernized farming techniques and incorporate the Internet of Things (IoT) monitoring adopted by the developed world. Using IoT-based real-time monitoring, crop management can become smart with enhanced yield. Smart plantation raises crop production and reduces wastage. The central aspect of this study is to provide an accessible and cost-effective solution for real-time monitoring and control of essential parameters, such as timely irrigation, that affect agricultural yield. Such tracking, in real-time, initially involves transferring all real-time sensor(s) data to the cloud for processing. Secondly, the processed real-time data will be available on an Android smartphone App, providing farmers with quick IoT-based situational awareness & control of an intelligent irrigation system with optimized water usage.

INTRODUCTION

The Internet of Things (IoT) refers to a network comprising physical entities such as electronic devices, humans, animals, and objects that are interconnected. These entities have the capability to detect, collect, and transmit data over the Internet autonomously, without requiring human involvement. Everything is fitted with specific identification marking. It is an advanced analysis platform for mechanized systems that use the identification, structure, tremendous knowledge and creativity of man-made consciousness to express a full system for an administration. In turn IoT is about expanding the internet's capacity beyond smartphones and computers [1]. IoT is transforming the world today. With aid of IoT, smart cities, connected vehicles and smart homes as shown in Figure 1 will transform anything around us into a digital system. It also has applications in the agriculture, safety, transportation and logistics industries. There are four primary components of IoT:

a) **Low Power Embedded System:** High output and low power consumption are the inverse factors which play an important role in electronic device design.

b) **Cloud Computing:** Data obtained from computers are placed on secure data servers and cloud computing takes place there.

c) **Big Data:** As IoT is heavily dependent on real time sensors. Therefore the usage of mobile equipment is scattered across any area and can cause large data influx.

d) **Network Connection:** In communication, where each physical entity is recognized by an IP address, internet connectivity is necessary. A network link is created between the devices using these addresses.

Today, technology has not exceeded the ideal goal of 100 % and here are the advantages and disadvantages of IoT:

Advantages of IoT

1. Optimal utilization of resources.
2. Decrease in manual labor.
3. Time efficiency.
4. Increase in data collection capacity.

Disadvantages of IoT

1. Safety.
2. Individual privacy.
3. Intricacy.

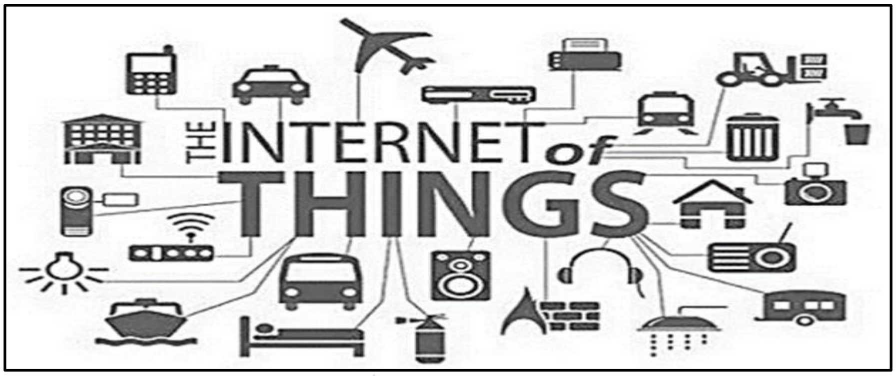

Figure 1: Depiction of IoT

Agriculture and IoT

IoT has the power to significantly alter people's lives everywhere. The constantly growing population will surpass 10 billion people in a few years. Agriculture business also must accept IoT to sustain such an overwhelming population. The need for more food will have to tackle the problems that arise in agricultural activities involving extreme climatic pressures, weather fluctuations and numerous other environmental impacts [2], [3], [4] and [5]. To secure the future of agriculture in Pakistan, it is crucial to raise awareness and implement essential farming techniques that can boost productivity and rekindle farmers' interest in this field. As illustrated in Figure 2, these advanced farming methods will assist farmers in reducing yield losses and enhancing efficiency. This approach involves a high-tech, capital-intensive method of crop production that is accessible to the general population in a sustainable way. Utilizing sensors, this IoT-based technology enables farmers to monitor field conditions remotely and even automate irrigation. It involves the application of information and communication technologies within the agricultural sector.

Figure 2: Smart Farming

IoT Architecture in Agriculture

The three (3) layers that make up this system's structure and their roles are explained as follows:

1) **Sensor layer:** The job of the sensor layer is to automatically and instantly change the statistics of real-world agricultural production by using digital translation or information that may be interpreted in the virtual environment in a number of ways. The information they gather is:

- Sensor data, such as soil moisture, temperature, pressure, gas concentrations, and humidity.
- Details about the product: name, model, cost, and attributes.
- Working condition: various equipment operating parameters, etc.
- Location information: The sensor layer's primary responsibility is to detect various types of data and collect information in the physical environment through sensing. Data is then transformed for automated information processing. A few approaches are included in this sensor architecture, including two-dimensional message identifiers, cameras, RFID tags, and sensor networks.

2) **Transport layer:** The role of this layer is to acquire and synthesize agricultural data acquired for processing from the sensor layer. This is considered to be the IoT's nerve center. Its framework is based on a combination of traffic operation centers, internet nerve and smart data centers.

3) **Application layer:** This layer's purpose is to interpret and process information gathered to develop the real world's digital awareness. This is defined as a link between IoT and business intelligence.

IoT Advantages for Agriculture

- With the help of centralized assessment administrations like cloud servers and farm field maps, more information can be gathered from any location that permits end-to-end live tracking and networking. IoT facilitates simple collection and manages to gather enormous volumes of knowledge from the devices used. [6, 7], and 8].
- With the careful application of sensors and even smart devices, IoT is thought to be a key component of smart farming. According to field experts, farmers might double their output by 72% by 2050.
- Utilizing the Internet of Things, production costs can be drastically reduced, increasing longevity and efficiency.

By utilizing the IoT productivity stage, application efficacy of energy, nutrients, fertilizers, pesticides, etc. will be further enhanced.

Applications of IoT in Agriculture

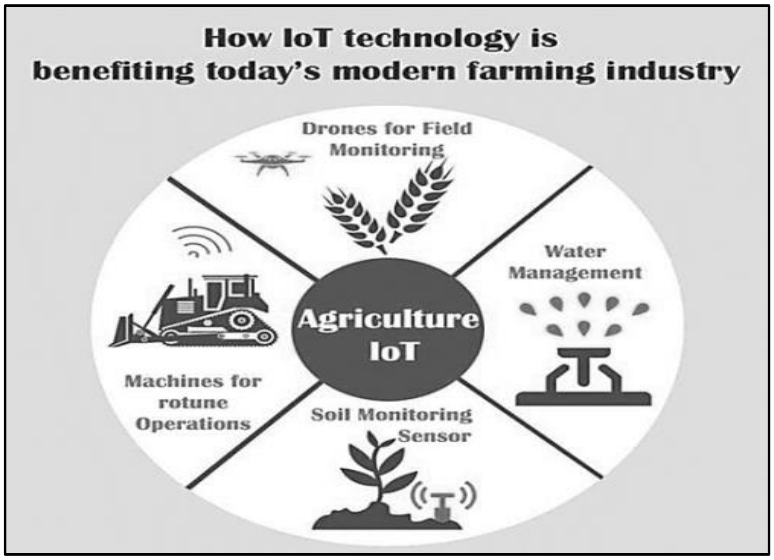

Figure 3: Applications of IoT in Agriculture

- Precision agriculture.
- Drones for farming.
- Monitoring of livestock.
- Intelligent greenhouses and so on, as depicted in Figure 3.

Motivation

The suggested design was inspired by specific issues that farmers confront, which include the fact that, at best, a lack of technology expertise is causing farming in Pakistan to stall. Additionally, they continue to use conventional farming practices, which result in less productive crops. With the help of the next technology, crop production can be increased while costs are decreased. This frequently lessens the demand on farmers to take out sizable debts in order to sustain their livelihoods or to produce respectable crop yields. Apart from these issues, a lack of money frequently results in farmers' output being hindered, and as a result, Pakistan's economy continues to be significantly impacted by the loss of a large portion of the country's fertile lands, which constitute a vital component of our GDP. In order to help farmers expand competitively even with limited capital and archive better production that is efficient and guaranteed, we are putting up an integrated farming method.

Objectives

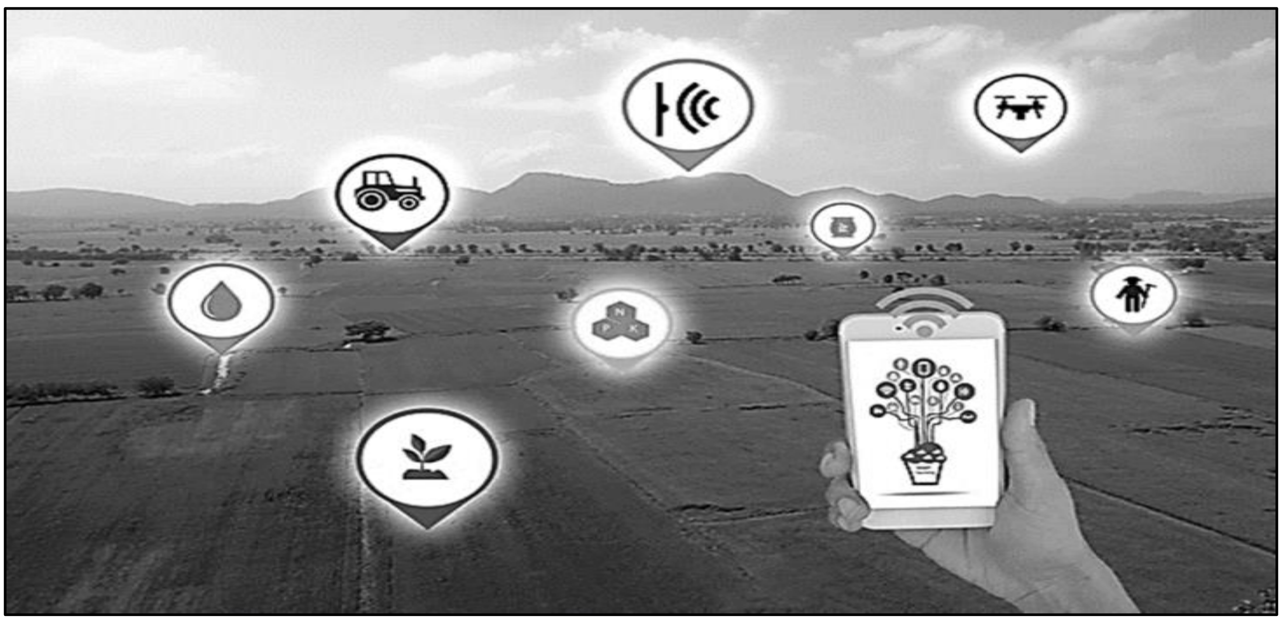

Figure 4: IoT based Smart Farm

1. Updating farmers with modern technologies and avoiding physical labor.
2. Reducing water wastage and improving crop production by supplying them with optimal conditions.
3. To be aware in real-time regarding threats such as extreme weather patterns and accelerating climate change.
4. As seen in Figure 4, design a useful layout and connect it to the cloud server and Android device for convenient access.

Design and Methodology

Sensors, Processors and applications are the fundamental building blocks of an IoT based infrastructure. Therefore, the block diagram shown in Figure 5 is the conceptual layout of our design that displays various blocks interconnected. The

Node Microcontroller Unit (NodeMCU) interfaces with the sensors, and the user's mobile device and web application display the sensor data. Farmers may take the appropriate actions to meet soil requirements since the mobile device and online app provide real-time access to changing sensor data.

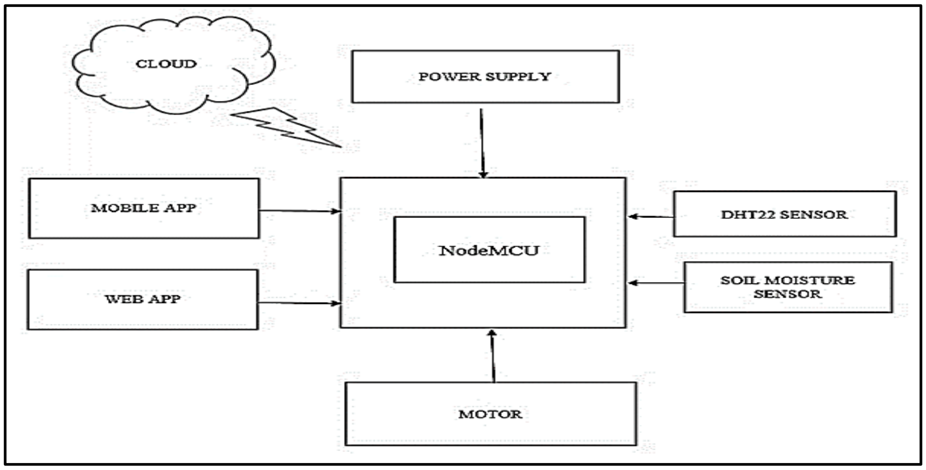

Figure 5: The Proposed Model's Block Diagram

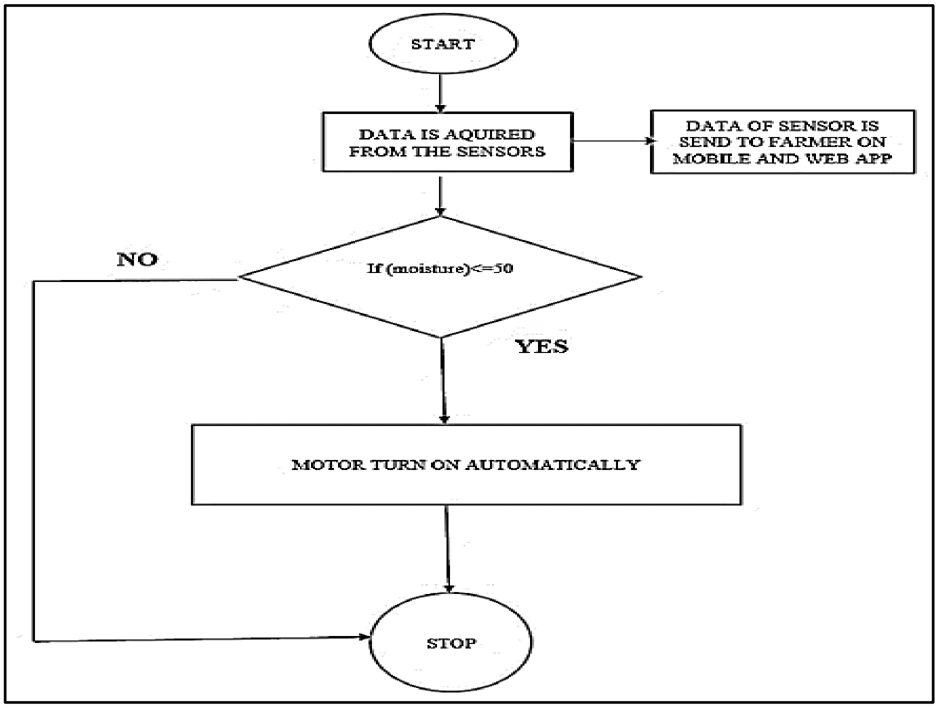

Figure 6: Flowchart of the Relay Connected Motor

After gathering data from various sensors, including those for humidity, soil moisture and temperature, the information is sent to the user's mobile device and web app. If the soil's water content falls below a specified threshold then the motor is automatically activated via the relay as illustrated in Figure 6.

Tools for Hardware

Illustrated in Figure 7, NodeMCU is a development kit and open-source firmware designed for creating Internet of Things devices. It includes hardware with an ESP-12 module and firmware that operates on an ESP8266 WiFiSoC. This package contains a single analog pin (A0). Furthermore, the board is equipped with digital pins (D0-D8). It also supports serial port communications such as SPI, UART, and I2C. [9].

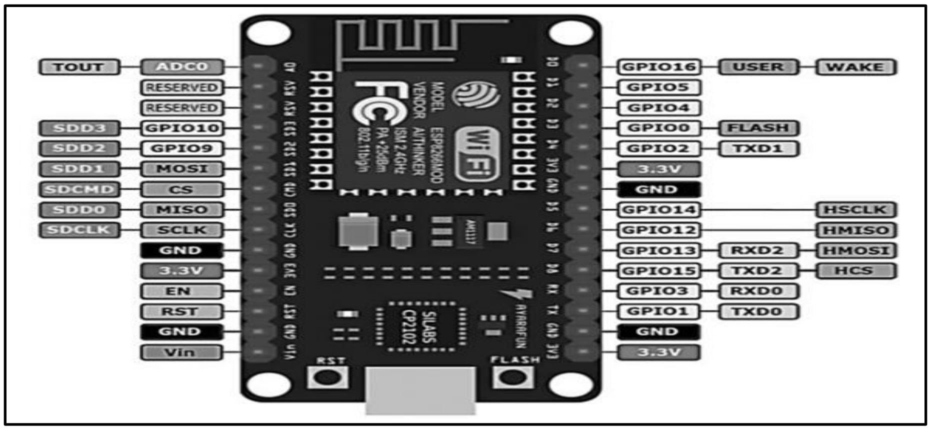

Figure 7: Pin Diagram of NodeMCU

DHT22 Sensor: As seen in Figure 8, the DHT22 is an affordable temperature and humidity sensor. Since this sensor has a digital output, it can be connected straight to the data pins of the microcontroller when utilizing ADC. Additionally, it has an eight-bit microprocessor that provides serial data for temperature and humidity readings. The four pins on this sensor are VCC, GND, DATA, and NC. It requires 3.3-5 volts of power to operate. This sensor's exceptional precision, anti-interference ability, economic efficiency, and quick reaction time are all noteworthy. A thermistor, which measures the conductivity of a liquid substrate that varies with temperature and humidity exchange is used to monitor humidity [10]. The "DHT.h" library in the Arduino IDE includes a function called read() that is utilized to gather data from the sensor.

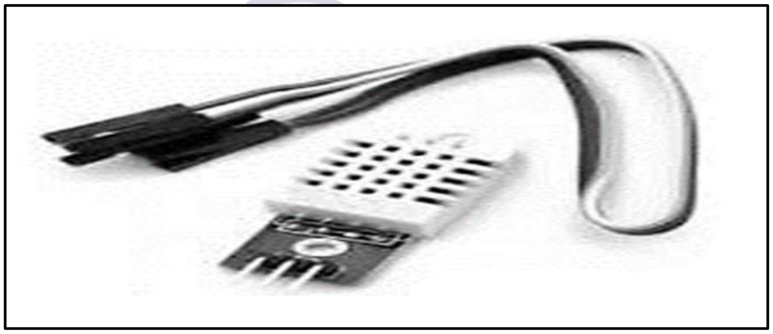

Figure 8: DHT22 Humidity and Temperature Sensor

Soil Moisture Sensor: The three pins on the moisture sensor are for analog input, ground, and input voltage, respectively. This sensor determines the soil's moisture content. As a percentage of the moisture content, the analog value will be dispersed between 0 and 100. Soil electric resistance is the characteristic that this technology makes use of. This sensor features two thrust probes that permit current to pass through the soil, as shown in Figure 9. It initially calculates the resistance factor to ascertain the water content. This implies that when the concentration of water increases, there will be reduced resistance and electrical conduction. Dry soil's limited conductivity causes resistance levels to rise. Consequently, it uses the soil's resistance property to calculate soil moisture. [11].

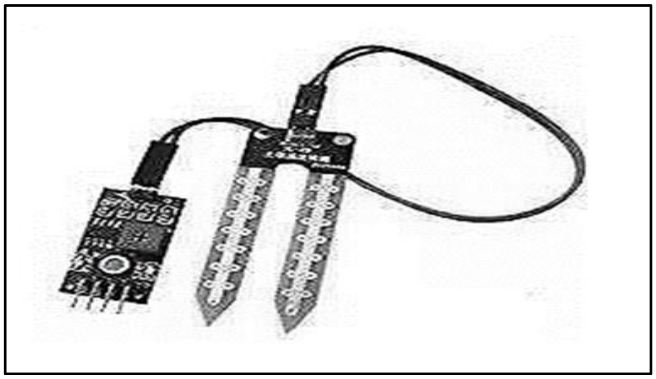

Figure 9: Soil Moisture Sensor

Relay: It is a switching device as shown in Figure 10. Some relays utilize an electromagnet to physically power a connection but solid state relays are also available where running a circuit through an individual low-power signal is necessary or where multiple circuits are operated by a single signal. Thus, this relay functions as an automatic switch that uses low current signal to work on high current circuits [12].

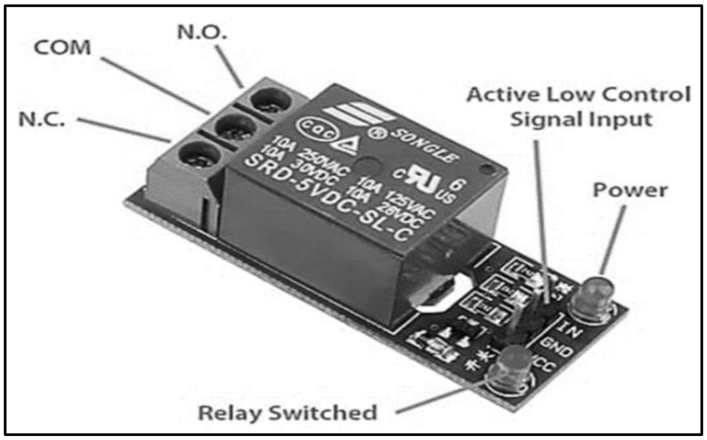

Figure 10: Switching Relay with Pin Configuration

How a Relay Works: Figure 11 explains how the relay in Figure 10 operates. As we can see, the control-switch and load connections help to supply electricity to the electromagnet. The electromagnet is powered as the magnetic field increases and current begins to flow through the control loop. By drawing the upper arm into the lower arm in accordance with the connections to load the power, a short circuit is created that aids. An open circuit is created and the connections are split apart and moving in opposing directions when the relay is de-energized. With the aid of an attracting force, the carrying armature would return to its initial position when the coil's current was present.

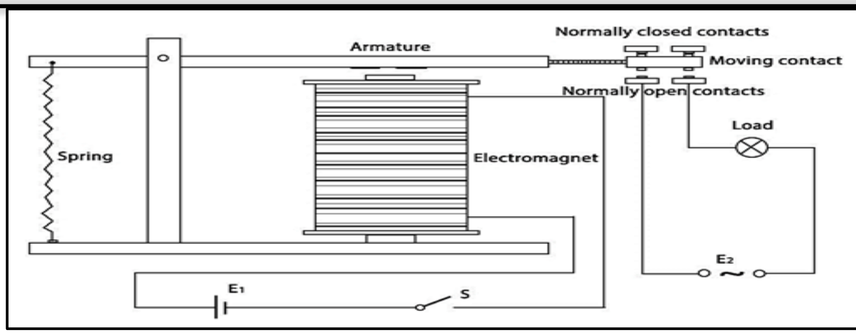

Figure 11: Working of Switching Relay

Water Pump: As seen in Figure 12, it is a mini submersible pump that runs economically and portable on 3-6 volts DC voltage. With very little current usage, it will need about 120 liters per hour. Since utilizing the engine without water could cause it to overheat and harm the unit's components, it is crucial to maintain the water level. This engine can also be used in hydroponic systems, controlled garden irrigation, and pool water flow [13].

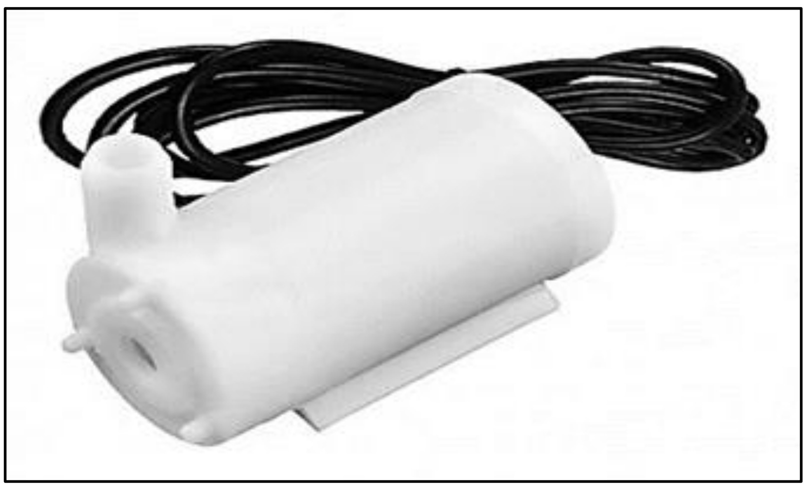

Figure 12: Submersible pump

Software

Integrated Development Environment (IDE) for Arduino: The Arduino IDE is an open-source programming platform that essentially writes and compiles code using an Arduino module. As seen in Figure 13, it is an official computer application that makes code compilation simple enough for even a non-technical individual with little experience with coding to understand how to use the Arduino IDE. The application is available for free on all Linux, UNIX, Windows, and Mac operating systems. The Arduino Mega, Arduino Uno, Arduino Leonardo, and many other Arduino modules are available. The device consists of a text editor for writing code, a text console, a message area, and an icon toolbar for common functions. Sketches are programs that use this software to compose code. This program's coding mostly makes use of C/C++ features. [14].

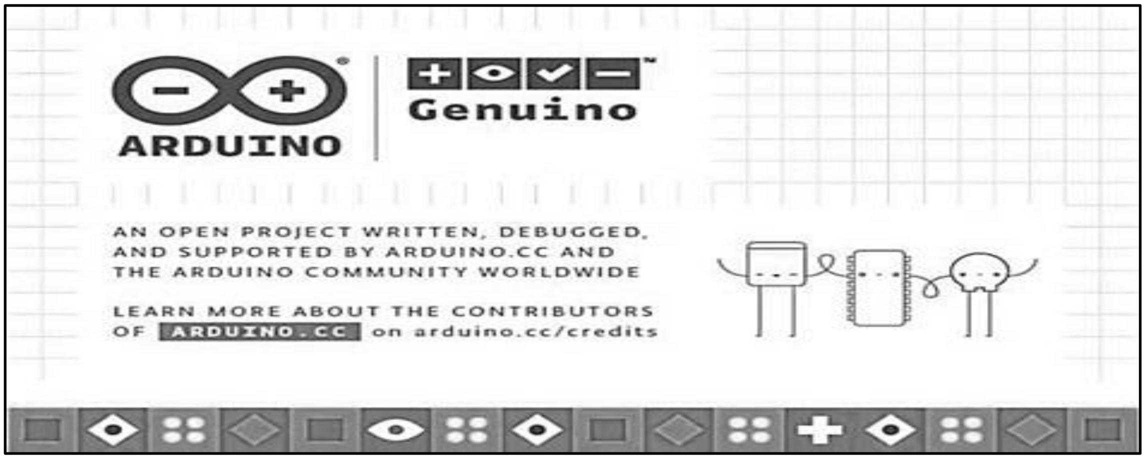

Figure 13: Arduino IDE

Blynk: As seen in Figure 14, it was primarily created for the Internet of Things. In addition to showing data from several sensors, this app can remotely manage devices. You may even examine and store information using this software [15]. There are three primary components to this platform: (a) Blynk App: A variety of widgets can be used to create incredible interfaces. (b) Blynk Server: Creates a network of contacts between smartphones and hardware. (c) Blynk Libraries: They manage both outgoing and incoming commands and enable communication between the client and server.

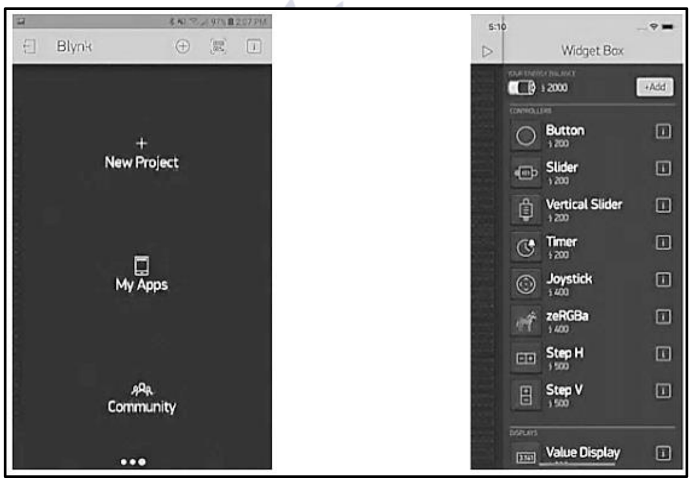

Figure 14: Blynk App and Widgets

ThingSpeak: The platform offers specific services that enable live data streaming on a cloud server for visualization, analysis, and aggregation. It provides real-time representations of data that has been published to a cloud server by various devices. It is capable of running MATLAB code. We can evaluate and process statistics as they come in online on this server. Prototyping frequently uses it. Smart devices that reside at the network's edge and are sensor devices gather data are shown on the left side of Figure 15. There is a cloud where data from multiple sources is analyzed in real-time. On the right side of Figure 15, the development of algorithms for IoT applications is illustrated [16]. Among the benefits of ThingSpeak are: (a) it is simple to set up IoT protocol devices to send data to the cloud. (b) Sensor data can be visualized in real time. (c) Gathering data from sources as needed. (c) Using MATLAB's power to interpret IoT data. (e) Creating IoT prototypes and systems without creating servers and software.

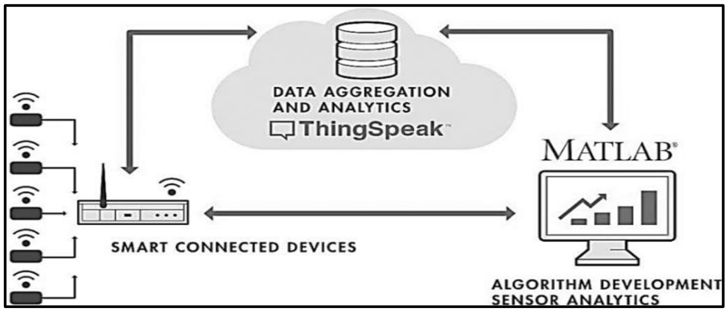

Figure 15: Connectivity of ThingSpeak

Results and Discussion

The prototype of our suggested design, which includes a NodeMCU, DHT22 sensor, soil moisture sensor, and relay-connected motor attached to a tiny simulated crop field, is depicted in Figure 16. The NodeMCU provides the framework for real-time temperature, humidity, and soil moisture monitoring. It also uses an ESP8266 WiFi module to send sensor data to the server and submit it to a smartphone or web application. The sensors have a dedicated power supply and are connected to the microcontroller, or NodeMCU. After reading the sensor values, the NodeMCU uploads the data to the cloud server. When the soil moisture value drops below a threshold value (in this case, 50), the relay turns on, causing the motor to turn on automatically (irrigation ON). When the soil moisture value rises to the threshold point (in this case, 50, as shown in Figure 6; it may be higher), the relay turns off the motor automatically (irrigation OFF), maintaining the field at optimal irrigation levels. It is crucial to keep in mind that the user of the system has total control over the threshold settings.

Figure 16: Experimental Setup

When Soil is DRY (9:30 AM Onwards):

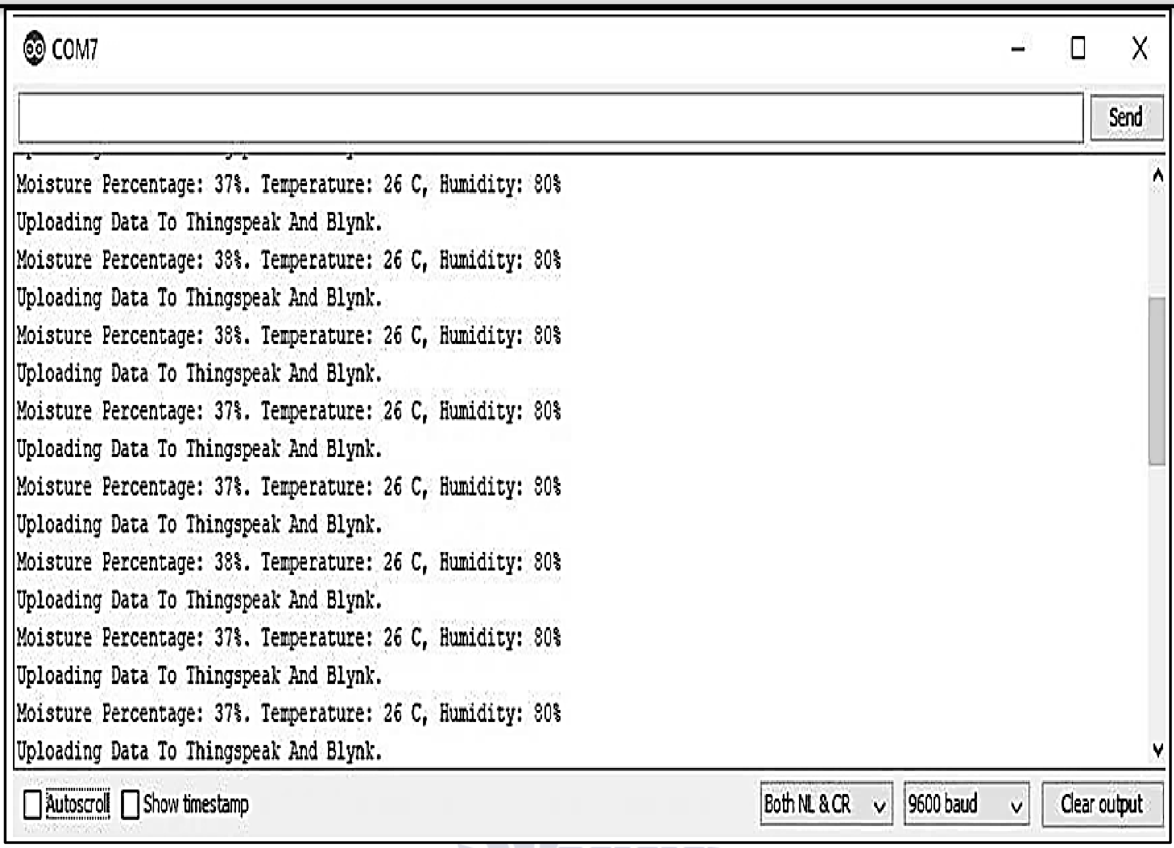

Figure 17: Sensors readings on Serial Monitor (DRY)

Figure 17 and Figure 18, in real-time, show value of temperature (26 degrees Celsius), value of humidity (80%) and value of soil moisture (38%) on the serial monitor and the mobile App respectively during day time when soil is dry. The Blynk App updates the readings as sensors data updates ensuring real-time monitoring.

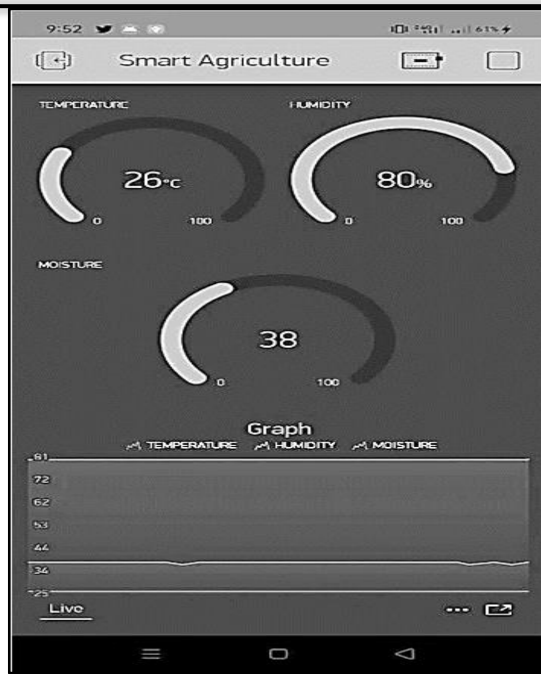

Figure 18: Readings on Blynk App (DRY)

When Soil is WET (11:30 AM Onwards - Deliberately Irrigated):

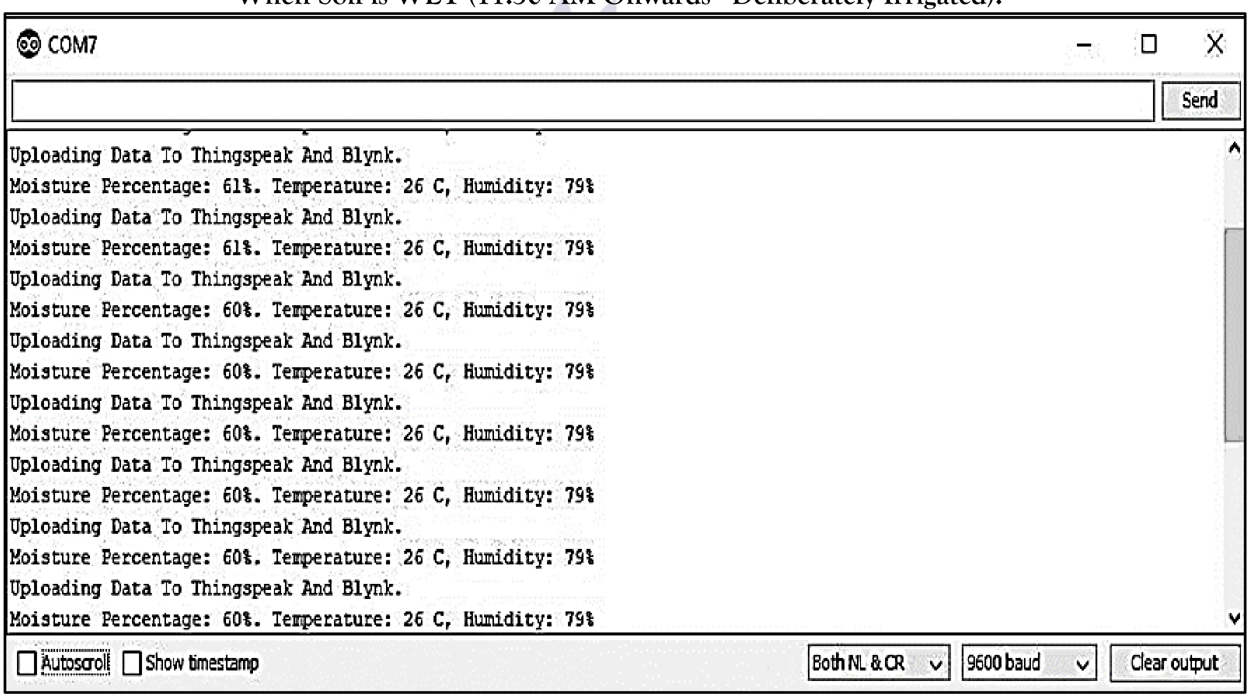

Figure 19: Sensors readings on Serial Monitor (WET)

When soil is intentionally irrigated during the day, Figures 19 and 20 display the temperature (26 degrees Celsius), humidity (79%) and soil moisture (61%), respectively, in real-time on the serial monitor and the mobile app.

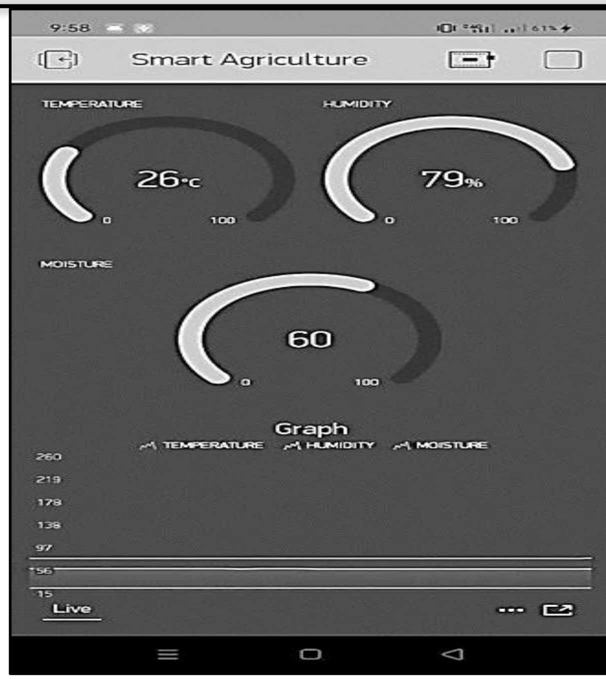

Figure 20: Readings on Blynk App (WET)

When Soil gets DRY again (5:00 PM Onwards – Irrigation cut-off at 12:30 PM):

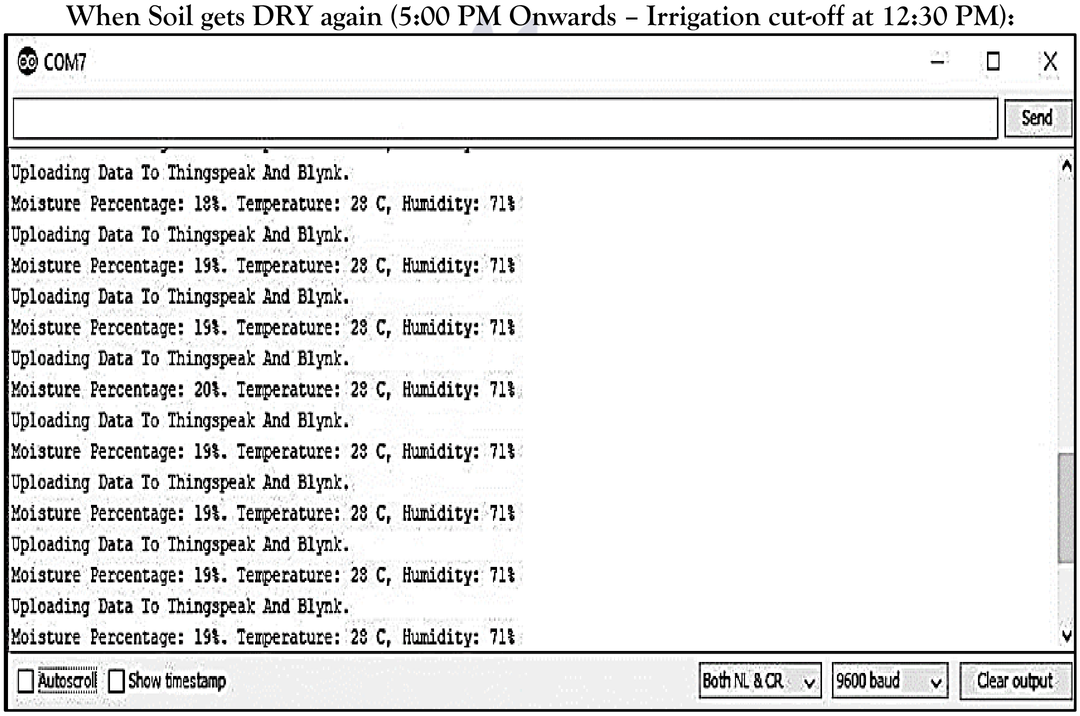

Figure 21: Sensors readings on Serial Monitor (DRY)

Figures 21 and 22 display the temperature (28 degrees Celsius), humidity (71–72%), and soil moisture (19%) in real-time on the serial monitor and mobile app, respectively, at 5 PM and after irrigation is turned off at 12:30 PM. As usual, when sensor data changes, the Blynk App refreshes the values.

Figure 22: Readings on Blynk App (DRY)

Based on the aforementioned data, we can conclude that at 9:30 a.m., when the temperature is low, the soil has high moisture content, and at 5:00 p.m., when the temperature rises by two degrees Celsius, the soil has low moisture content. Moreover, the future scope of this research can include numerous other soil sensors e.g. Rain and pH sensors which are easily commercially available. That inclusion will make the methods of forecasting and analysis more detailed. Additionally, the suggested model can be altered to provide various data mining algorithms for the analysis of agricultural data. This study proposes, designs, and tests an Internet of Things-based crop management system. Despite the accomplishment of its objectives, different techniques can be recommended to improve the performance of the proposed design such as: (a) As the NodeMCU has only one analog pin so a multiplexer can be connected to it for providing more analog pins which will help in connecting more input parameters. (b) Rain sensors can be used in monitoring soil moisture and it would also help in stopping water wastage. (c) Light Dependent Resistor (LDR) sensors can be used to monitor light intensity. If crops need more light, electric bulbs can be used in greenhouse environments. (d) ph sensors can be used to monitor the soil quality and to monitor the deficiency of minerals. (e) Motion sensors along with buzzers can also be used to save crops from cattle and birds. And finally, in order to reduce labor, system connected drones can be used to spray pesticides.

Conclusion

The use of the Internet of Things (IoT) in agriculture is explained in detail by the suggested practical model in this study. By predicting the ideal agricultural irrigation schedule for a particular area's soil, this model aids in maximizing crop output. ThingSpeak facilitates real-time soil condition sampling, allowing for additional crop condition analysis of the collected data. The record of multiple local soil moisture, temperature, and humidity samples taken at various times of the day is presented in this study. Nowadays, Cloud storage & access technology also enables farmers to increase production, evaluate their strategies in real-time, and tackle crop diseases through up-to-date monitoring. The system proposed in this paper is productive, commercially achievable, and cost-effective. It also focuses on maximizing water resource use, combating problems such as water shortages, and guarantees sustainability. This paper reflects on the use of IoT technology in agriculture, and the ideas presented here stress the use of innovative farming practices, increasing efficiency, resulting in efficient countering of resource limitations.

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