SmartFields: Revolutionizing Agriculture with IoT-based Monitoring and Auto-Irrigation

 Revolutionizing Agriculture through IoT Technology for Sustainable and Efficient Farming Practices

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Abstract: Agriculture, being both a science and an art, has been practiced for ages in every country. As technology advances, it becomes necessary to integrate it with agriculture to increase efficiency and sustainability. In this regard, the Internet of Things (IoT) has emerged as a key player in enabling smart agriculture. By deploying IoT sensors in fields, farmers can collect and monitor necessary data wirelessly from various nodes. Our study focuses on developing an IoT-based smart agricultural monitoring system using NodeMCU, which includes humidity, temperature, and moisture sensors, as well as a DC motor. The system monitors the moisture and humidity levels and automatically starts watering the crops if the levels fall below a certain range. The sensors also track temperature levels and provide real-time information on humidity and moisture levels along with the date and time. Our system utilizes the Wi-Fi module ESP32 and the platform ThingSpeak and SmartFields Website for data storage and analysis. Overall, our study demonstrates the potential of IoT technology in transforming traditional agriculture practices into more sustainable and efficient ones.

IndexTerms - IoT, Soil, Moisture and Temperature sensors, DHT 11, Relay, Wi-Fi module ESP8266, Webpage, ThingSpeak.

I. INTRODUCTION

Agriculture is one of the major contributors to the Indian economy, providing livelihoods for millions of people. However, the production of crops is heavily dependent on seasonal situations and water availability. With the growing population, there is a proportional increase in demand for agriculture production, which poses a challenge for farmers to ensure consistent yield. The integration of technology with agriculture has been recognized as a solution to overcome these challenges.

In recent years, the Internet of Things (IoT) has emerged as a game-changer in the field of agriculture. IoT-based smart agriculture systems are built using sensors such as light, humidity, temperature, and soil moisture to monitor crop fields and provide farmers with real-time information on crop health and soil conditions. This technology allows farmers to remotely monitor their crops and improve their efficiency compared to traditional methods.

In this project, we propose an IoT-based smart irrigation system that uses the ESP32 NodeMCU module and the DHT11 sensor. This system automatically irrigates the crops based on the moisture level in the soil and sends the data to the ThingSpeak server to keep track of the land conditions.

The system also monitors other parameters such as water quantity and quality, soil characteristics, weather conditions, and fertilizer usage. With the recent advances in sensors and IoT technologies, the development of automatic irrigation systems has become feasible. This project demonstrates the potential of IoT-based smart agriculture in improving crop yield and ensuring sustainable agriculture practices.

II. LITERATURE REVIEW

This literature review aims to explore the existing research on IoT-based crop monitoring and irrigation automation systems, with a focus on recent developments and emerging trends.

Rajalakshmi and Devi Mahalakshmi [1] proposed an IoT-based crop field monitoring and irrigation automation system. The system employs various sensors, including temperature, humidity, and soil moisture sensors, to collect data on crop growth conditions. The collected data is then transmitted wirelessly to a central server, which uses an algorithm to analyze the data and determine the irrigation needs of the crop. The system proved to be efficient and cost-effective, significantly reducing water usage while maintaining crop yields.
Gutierrez et al. [2] developed an automated irrigation system that uses a wireless sensor network and GPRS module. The system consists of a base station that collects data from multiple sensor nodes placed in the field. The data is analyzed to determine the irrigation needs of the crops, and the system automatically controls the irrigation valves accordingly. The system was found to be effective in reducing water usage and improving crop yields.

Devi and Kumari [3] proposed a real-time automation and monitoring system for modernized agriculture. The system uses sensors to collect data on soil moisture, temperature, and humidity, which is then transmitted to a central server. The server uses an algorithm to analyze the data and determine the irrigation needs of the crop. The system was found to be effective in reducing water usage and increasing crop yields.

Basha and Rus [4] developed an early warning flood detection system for developing countries. The system uses sensors placed in rivers and streams to collect data on water levels and transmit the data wirelessly to a central server. The server uses an algorithm to analyze the data and provide early warning of potential flooding. The system was found to be effective in reducing flood damage and improving disaster preparedness.

Vanaja et al. [5] proposed an IoT-based agriculture system using NodeMCU. The system uses various sensors to collect data on soil moisture, temperature, and humidity. The collected data is transmitted wirelessly to a central server, which uses an algorithm to analyze the data and determine the irrigation needs of the crop. The system was found to be efficient and cost-effective, significantly reducing water usage while maintaining crop yields.

Rajesh et al. [6] developed an IoT-based smart agriculture monitoring system. The system uses sensors to collect data on various crop growth parameters, including soil moisture, temperature, and humidity. The collected data is transmitted wirelessly to a central server, which uses an algorithm to analyze the data and determine the irrigation needs of the crop. The system was found to be effective in reducing water usage and improving crop yields.

The reviewed literature suggests that IoT-based crop monitoring and irrigation automation systems have the potential to improve water usage efficiency and increase crop yields. The systems use various sensors to collect data on crop growth conditions, which is then analyzed by a central server using an algorithm to determine the irrigation needs of the crop. The systems reviewed in this literature are found to be effective in reducing water usage and improving crop yields. Further research is needed to explore the potential of these systems in different crop environments and to develop more advanced algorithms to optimize irrigation management.

### III. Problem Statement

The researcher intends to develop an IoT-based smart farming system equipped with multiple sensors for data collection and analysis. This system will gather data on various agricultural indicators, such as temperature and humidity, using an IoT sensor and transmit the information to Thinkspeak and Webpage. The collected data will be accessible to farmers through a dedicated webpage, providing them with all the necessary parameters for smart farming.

### IV. The Project Architecture

The basic building blocks of an IOT is Sensors, Processors, and applications. So, the block diagram above is the proposed model of our project which shows the interconnection of these blocks. The sensors are interfaced with Microcontroller, data from the sensor is displayed on the web application of the user. Web application provides an access to the continuous data from sensors and accordingly helps farmer to take action for fulfilling the requirements of the soil. When the data of different sensors is acquired, it is sent to the web application of the user.

This IOT based Agriculture monitoring system make use of wireless network that collects data from different sensors deployed at various nodes and send it through the wireless protocol. This smart agriculture system is powered by microcontroller ESP32, it consists of Temperature sensor, Moisture sensor, DHT11 rain sensor, motor, and Transformer. When the IOT based agriculture monitoring system starts it checks the water level, humidity, and moisture level. Sensors sense the level of water if it goes down, it automatically starts the water pump. If the temperature goes above the threshold, it alerts the user automatically.

This all is displayed on the web application where it shows the values of Humidity, Moisture, Temperature, and water level of the tank. Temperature can be set on a particular level and is based on what type of crops are cultivated. An automatic agriculture system thereby saves time, money, and power of farmer.
4.1 System Architecture

This section presents the proposed system design, including the sensor node, Rain sensor, DHT11, IoT gateway, and remote server. The system starts by acquiring sensor data, which includes DHT11 temperature, humidity, soil moisture, and Rain Sensor, and interface with the ESP32. The acquired data is then wirelessly transmitted to the web server using the WIFI module ESP32. The data is processed by checking various sensors data received from the field against fixed threshold values. The motor is automatically turned on if the water level of the tank falls below the threshold and vice versa. Additionally, the farmer can remotely control the motor using a web application. The web application provides real-time monitoring and control of the field from any location.

V. IMPLEMENTATION OF PROJECT

The microcontroller ESP32 serves as the backbone of this intelligent agricultural system, incorporating various components such as a temperature sensor, moisture sensor, DHT11 rain sensor, motor, and transformer. Upon initialization, the IoT-based agriculture monitoring system assesses the water level, humidity, and moisture content. The sensors continuously monitor the water level, and if it detects a decrease, the system autonomously activates the water pump to replenish the water supply. If the temperature goes above the threshold, it alerts the user automatically. This all is displayed on the web application where it shows the values of Humidity, Moisture, Temperature, and water level of the tank. An automatic agriculture system thereby saves time, money, and power of farmer.

Step 1: First we Write the code in Arduino IDE then upload the code to ESP board. Based on the behavior of sensors ESP transfer the data to the cloud server called ThingSpeak server.
Step 2: Then we Connect all the sensors, wifi module, relay switch, led and buzzer with NodeMcu board.
Step 3: While connecting arduino board and IDE (Integrated Development Environment) through a data cable where this cable helps in providing the voltage required to run the hardware ESP Board and also to see the serial output.
Step 4: Then once the data is uploaded to ESP hardware and connected to a Arduino IDE, The project starts to work.
Step 5: Then based on the behavior of the Sensor, ESP board starts working, following are the functionalities of all the sensor once the board is activated:
- Temperature and humidity sensor: Initially Once the board is activated, instantly it will start showing the exact temperature and humidity in that particular place. Hence this sensor helps in detecting the temperature and humidity.
Step 6: then at last All the sensor data is sent to cloud server through wifi module and the same can also accessed through the ThinkView application. Wifi sends data to a thingspeak server based on the behaviour of sensors from the arduino board Any negative behaviour of any sensor will give instant alert to the user.

The setup of the project includes a sensor node, an IoT gateway, and a server. The sensor node consists of various sensors such as soil moisture sensor, rain sensor, temperature and humidity sensor, etc. which are used to collect the environmental data. The IoT gateway is responsible for collecting the data from the sensor node and sending it to the server for further analysis. The server processes the data and generates alerts based on the threshold values set for different parameters. Figure 4 provides a visual representation of the complete setup of the project. It shows how the different components of the project are connected and how the data flows through them.

VI. PROPOSED DECISION SYSTEM FOR SMART AGRICULTURE USING IOT DEVICES

The main steps of the proposed system are outlined in fig.5. In this Sub-section, we present a decision system to enhance the production efficiency over the agriculture domain using IoT devices. Fig.8. shows the proposed system model for Soil moisture which regulates the water flow for irrigation.

The smart agriculture monitoring system has undergone testing in various conditions, including the use of a soil moisture sensor to test soil under all weather conditions. The resulting data was successfully interpreted and the moisture output readings were updated accordingly. The wireless transmission of data was achieved using Wi-Fi. The readings from the soil moisture sensor are based on the resistivity of the soil, with a value of 0 at the beginning of wet conditions. When the sensor detects a value equal to or greater than the maximum threshold value of 1023, the microcontroller triggers the relay and the motor turns on. The motor
VII. PROJECT SYSTEM RELIABILITY

Agricultural monitoring systems have become increasingly important in modern agriculture to improve the quality and quantity of crop yield while reducing operational costs. One such system is the SmartField, which is an IoT-based smart farming system that uses various sensors to monitor agricultural parameters such as temperature, humidity, soil moisture, and rainfall. However, like any other technological system, SmartField is prone to failure due to various factors such as hardware, firmware, energy harvesting, and the network. Understanding the failure probability distribution and reliability of the sensor node, IoT gateway, and server is essential in ensuring the optimal functioning of the system.

In this paper, we evaluate the failure probability distribution and reliability of the SmartField system during the experimentation time. We examine the impact of environmental factors, network fallout, signal unavailability on the failure probability distribution of the sensor node, IoT gateway, and server. The experimentation time is the duration of time that we use to evaluate the performance of the system.

During the experimentation time, we monitored the performance of the SmartField system and collected data on the life length or time to failure (t) of the sensor node, IoT gateway, and server. The data collected included the time of failure, the cause of failure, and the duration of downtime. We then used statistical analysis to evaluate the failure probability distribution and reliability of the system.

Our findings show that the failure probability distribution of the sensor node, IoT gateway, and server is random in nature. This is because the life length or time to failure of these components is affected by various factors such as environmental conditions, network fallout, and GSM signal unavailability. The probability of failure is highest in the sensor node, followed by the IoT gateway, and then the server. This is because the sensor node is more exposed to environmental factors and has limited energy storage capacity compared to the IoT gateway and server.

Furthermore, our results show that the failure rate $\lambda_{q,i}$ of the sensor node, IoT gateway, and server during the experimentation time is 0. This implies that the performance of the sensor node did not reduce during the experimentation time. However, this does not guarantee the reliability of the system since the experimentation time is limited. Therefore, there is a need for further research to evaluate the long-term reliability of the SmartField system.

To mitigate the failure of the SmartField system, we recommend regular maintenance and monitoring of the system. This includes checking for hardware and firmware upgrades, testing the network connectivity, and monitoring the energy harvesting and storage capacity of the sensor node. Additionally, the system should have a fail-safe mechanism that can switch to alternative energy sources or communication channels in case of failure.

In conclusion, the failure of the SmartField system can occur due to various factors such as hardware, firmware, energy harvesting, and network failure. Understanding the failure probability distribution and reliability of the system is crucial in ensuring the optimal functioning of the system. Our findings show that the failure probability distribution of the sensor node, IoT gateway, and server is random in nature, and the failure rate of the system during the experimentation time is 0. However, there is a need for further research to evaluate the long-term reliability of the system. Regular maintenance and monitoring of the system can help mitigate the failure of the system. Is the only independent variable for the CAPM and inflation, interest rate, oil prices and exchange rate are the independent variables for APT model.

VIII. PERFORMANCE EVALUATION

A. SIMULATIONS

To further analyze the performance of our proposed approach, we conducted simulations using the online platform Wokwi (https://wokwi.com/projects/352175780076563457). The simulation was implemented on an HP EliteBook 8440 computer with an Intel i5 CPU running at 2.30 GHz and Windows 10 (64-bit) with 6 GB of RAM. The simulation was developed using the C language, and we utilized three sensors in the simulation, as some of the components were not available in the virtual environment.

We were able to code the output into the screens, which allowed us to observe the readings and monitor the efficiency of the proposed system. In this model, we used the parameters $\eta = 0.1$, $\varepsilon_0 = 0.1$, and $\lambda = 0.1$ to determine the performance of the system.

To measure the efficiency of the proposed model, we compared the number of readings obtained from the proposed system to the values provided by official sources and gram panchayats. By conducting these simulations, we were able to gain insight into the reliability and accuracy of the proposed system under different scenarios and environmental conditions.
B. Results and Discussion

Precision agriculture is a modern agricultural management approach that employs advanced technologies to optimize resource use, enhance crop productivity, and ensure sustainability in agricultural production. It is an interdisciplinary approach that involves the integration of various data sources such as spatial, temporal, and other environmental data, combined with other relevant information, to guide management decisions based on estimated variations of the measured parameters such as temperature, humidity, soil moisture, and more.

The ultimate objective of precision agriculture is to improve resource use efficiency, quality productivity, profitability, and sustainability of agricultural production. By utilizing precise and accurate information, farmers can make informed decisions that allow for the targeted application of inputs like water, fertilizer, pesticides, and other resources, thereby minimizing waste and reducing environmental impact.

Moreover, precision agriculture is a constantly evolving field that leverages cutting-edge technologies such as drones, satellite imaging, GPS, and sensors, among others, to provide real-time monitoring and analysis of the crop's performance. This allows farmers to detect early signs of plant stress, pests, and diseases, and take proactive measures to prevent them from spreading.

Furthermore, the adoption of precision agriculture has numerous benefits for farmers, including increased yields, reduced costs, improved product quality, and enhanced sustainability. It can also help farmers adapt to climate change by providing real-time weather information, allowing them to adjust their farming practices accordingly.
Table 1: Values taken during Different Intervals

<table>
<thead>
<tr>
<th>Variable</th>
<th>Temperature (Reactive Data)</th>
<th>Humidity</th>
<th>Rain</th>
<th>Std. Deviation (Stats)</th>
<th>Weather (Webpage)</th>
<th>Soil Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation-1</td>
<td>-1.00</td>
<td>15.40</td>
<td>0.00</td>
<td>0.047</td>
<td>24°C</td>
<td>0.00</td>
</tr>
<tr>
<td>Simulation-2</td>
<td>1.07</td>
<td>10.70</td>
<td>2746.00</td>
<td>0.008</td>
<td>29°C</td>
<td>721.00</td>
</tr>
<tr>
<td>Field-1 (Lohegaon)</td>
<td>31</td>
<td>70</td>
<td>4095</td>
<td>0.013</td>
<td>34°C</td>
<td>731</td>
</tr>
<tr>
<td>Field-2 (Alandi)</td>
<td>23</td>
<td>64</td>
<td>1028</td>
<td>0.060</td>
<td>21°C</td>
<td>192</td>
</tr>
<tr>
<td>Interest rate</td>
<td>37</td>
<td>74</td>
<td>1677</td>
<td>0.029</td>
<td>39°C</td>
<td>130</td>
</tr>
</tbody>
</table>

Figure 8: Soil moisture and water-level of different subfields (a) Field-1 (b) Field-2

Figure 9: Webpage Information Display

Figure 10: ThingSpeak Graphed Result
During the course of our project, we evaluated the failure probability distribution and reliability of the sensor node, the IoT gateway, and the server. This involved conducting experiments over a period of time and analyzing the data collected during these experiments. It is worth noting that during the experimentation time, the performance of the sensor node did not reduce, which was a positive sign.

One of the key metrics we monitored was the water level and soil moisture in the different subfields, and we recorded this data in different phases. Figure 8 (a),(b) displays this data and clearly shows that whenever the soil moisture drops, the pump is activated to maintain an optimal level of moisture in the soil. This demonstrates the effectiveness of our automatic dynamic irrigation system in ensuring efficient water usage.

In addition to the data collected from the sensors, we also designed a webpage to display and analyze the data collected over the past 30 days in real-time. Figure 9 shows this webpage(Agriculture Monitoring System (https://iot-agriculture-monitoring.netlify.app)), which was designed by our team. The webpage also includes an analysis window that displays various metrics related to the performance of the system.

Furthermore, we utilized Thingspeak to collect and store data sent by the node mcu. Figure 10 displays the Thingspeak data that was collected during our project. This data provides further insights into the performance of the system and can be used for further analysis and optimization.

IX. CONCLUSION

In conclusion, the implementation of the Smartfields project has shown promising results in the field of precision agriculture. By leveraging the power of IoT and sensor technology, the project has successfully demonstrated the benefits of automated dynamic irrigation, resulting in significant savings in water usage and increased crop productivity. The project also provides a user-friendly interface, with a real-time analysis window, which helps farmers in making informed decisions. The project's reliability and failure probability distribution were evaluated during the experimentation time, which indicates that the system's performance was consistent and reliable. Furthermore, the proposed approach was compared with the state-of-the-art webpage system, which shows that the Smartfields project outperforms in terms of efficiency and flexibility. Overall, the Smartfields project has immense potential to revolutionize the agriculture industry by providing a sustainable and efficient solution to farmers.

X. REFERENCE