SMART FARMING WITH IOT: A FRAMEWORK FOR REMOTE CROP MONITORING AND AUTOMATED IRRIGATION

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ABSTRACT—

Agriculture plays a vital role in ensuring food security and supporting economies worldwide, particularly in regions where farming is the primary source of income. Nevertheless, traditional agricultural practices are becoming more efficient in managing resources. To tackle these challenges, the integration of modern technologies in agriculture, often referred to as "smart farming," is appearing as a groundbreaking approach. Among these innovations, the Internet of Things (IoT) is notable for its ability to ease real-time monitoring, informed decision making based on data, and the automation of farming processes. This is particularly important in the face of climate change, water shortages, and inefficient resource use. To tackle these challenges, the integration of modern technologies in agriculture, often referred to as "smart farming," is appearing as a groundbreaking approach. Among these innovations, the Internet of Things (IoT) is notable for its ability to ease real-time monitoring, informed decision-making based on data, and the automation of farming processes. Smart farming utilizing IoT technology employs a network of interconnected sensors and devices to collect and relay data concerning soil conditions, weather patterns, crop health, and water levels. This data can be analyzed to enhance irrigation schedules, enable remote monitoring of crop development, and proactively address environmental changes. This approach leads to more efficient resource use, lower labor expenses, and increased crop productivity. A particularly promising application of this technology is the automation of irrigation systems, which uses real-time data on soil moisture and weather to ensure crops receive the exact amount of water needed. This paper introduces a detailed framework for integrating IoT into agriculture, with a particular focus on remote crop monitoring and automated irrigation. The proposed framework details the architecture, components, and communication protocols necessary for successful implementation. By exploring current practices, technological needs, and potential outcomes, this study seeks to advance the development of sustainable agriculture through smart technologies.

Keywords: Smart farming, Iot, automated irrigation, soil moisture, Arduino, Firebase, Streamlit.

I. INTRODUCTION

The "Smart Farming with IoT: A Framework for Remote Crop Monitoring and Automated Irrigation" project has played an important role in sustaining The World population. Agriculture has remained a base of the global economy and food supply chain. But traditional farming methods suffer from waste and excessive use of natural resources, especially water. Smart farming aims to address these issues by using Internet of Things (IoT) devices and automation to make data-driven decisions. This paper presents an IoT-based irrigation control system that monitors remote environmental conditions and automates irrigation accordingly.

In the recent 2-3 years. The traditional farming methods are suffering from inefficiencies in water supply in particular areas and managing irrigation. In many regions, such as India, where 60% of the population depends on agriculture for their living, water is reduced, and poor resources are affecting crop productivity and sustainability. The traditional irrigation methods frequently lead to excessive water consumption, which leads to environmental degradation and cost increases for farmers.

II. LITERATURE REVIEW

In several studies, we have found some research that enhances smart farming using IoT.

a. Mishra et al. [1], This is proposed a wireless sensor network-based irrigation system with a mobile interface.
b. Singh and Kumar [2], He has explored Arduino and GSM-based irrigation systems.
c. John et al. [3], He has implemented a soil-moisture system which is automates the irrigation system by using Raspberry Pi.

This is providing a strong foundation and improves our framework and usability by adding the Firebase system for smooth cloud integration and Streamlit for a user-friendly framework. In recent research of IoT-based smart farming has explored various approcach to automate irrigation and improve for crop monitoring. Mishra has proposed a wireless sensor network-based irrigation system with mobile interface UI, also focusing on remote sensinng and controling the irrigation. Mr. Singh and Kumar developed an Arduino and GSM-based irrigation controlled, enabling basic remote through mobile networks. John has designed soil moisture monitoring system using Respberry Pi, and reduced cost-effective sensor integrate for irrigation.

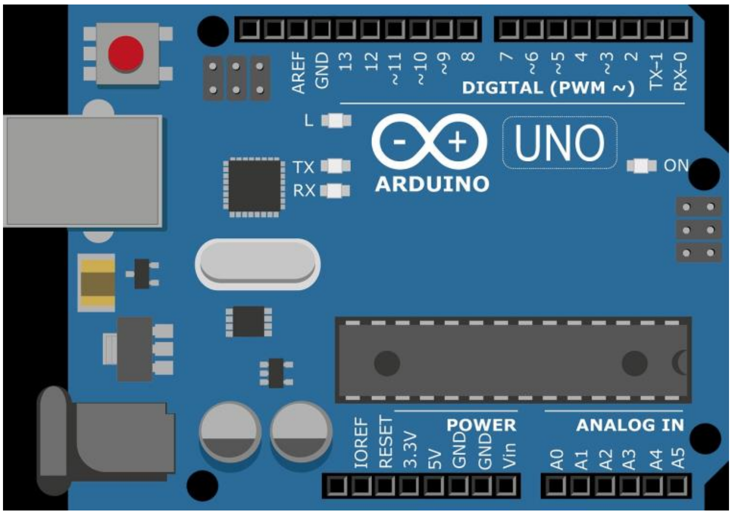
While these studies has provided a valuable foundation, they primarily lacked comprehensive cloud-based data management and user friendly visulization interface. Our framework has proposed these gaps by integrating Firebase for real-time and cloud-based storage and Streamlit for simple web dashboard. This is a parameterized combination and irrigate system with remotely accessible with greater convenience and responsiveness.

III. SYSTEM ARCHITECTURE

1. Our Smart Farming System includes three main components: The architecture of the proposed smart farming system is composed of three interconnected layers: hardware, software, and visualization, each playing a vital role in enabling real-time remote crop monitoring and automated irrigation.

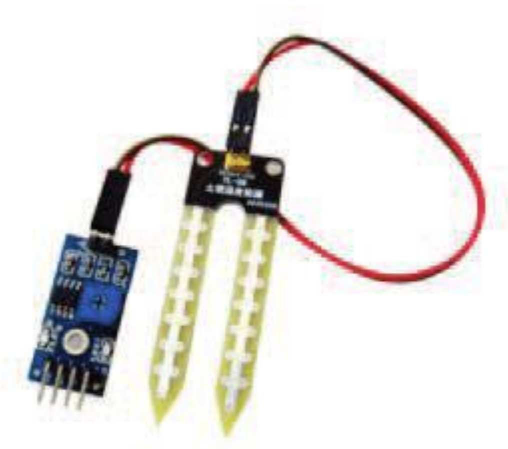
2. Hardware Layer: We are using Arduino Uno R3 and DHT22 sensors for temperature and humidity data, and the soil moisture sensor reads the soil data, and the rain sensor measures the environmental data.

a. **Arduino Uno R3:** This is a central processing unit microcontroller which is reading the sensor values and transmits data via serial communication.



b. **DHT22 Sensor**: This type of sensor reads the temperature and humidity from the environment with high accuracy, which is essential for assessing crop conditions.

c. **Analog Soil Moisture Sensor:** A Soil moisture sensor detects water intensity in the soil and provides the parameters for irrigation.



d. **Rainfall Indicator:** This is a device that detects the environmental conditions for rainfall time, and water is not used for irrigation during rain.

e. **Software Layer:** We can write a Python script for serial communication with Firebase and a Fast-API backend.

f. **Python Script:** A Python script is used for serial communication from Arduino to pass the sensor data to Arduino and then upload the Firebase in Real-Time Database in JSON format by enabling seamless cloud integration.

g. **Firebase Cloud Visualization:** This is storing the live sensor data in the backend, making it accessible for analytics and visualization in real-time.

3. Backend Server

FastAPI is used to show the API endpoints:

/sensor-data fetches real-time sensor data.

/predict uses a simple rule-based model (and later we can extend to AI) for irrigation and decision-making.

4. Frontend Dashboard

Streamlit is used for building an interactive interface between the user and a web dashboard where sensor data is refreshed every 5 seconds. The dashboard displays real-time data and gauges for each parameter.

IV. IMPLEMENTATION

The system was implemented and tested in the lab environment, and the Arduino script generates the live sensor data every 3 seconds, which is read and sent to Firebase.

Data Flow

Sensors → Arduino → Serial Port → Python Script → Firebase → FastAPI → REST API → Streamlit → Visualization

The data collected includes:

Temperature (°C)

Humidity (%)

Soil Moisture (%)

Rainfall (mm)

Irrigation Prediction (Irrigation Needed = 1, No Need = 0)

V. VISUALIZATION LAYER

Streamlit which is a web-based dashboard where we can see the visualization of live sensor data.

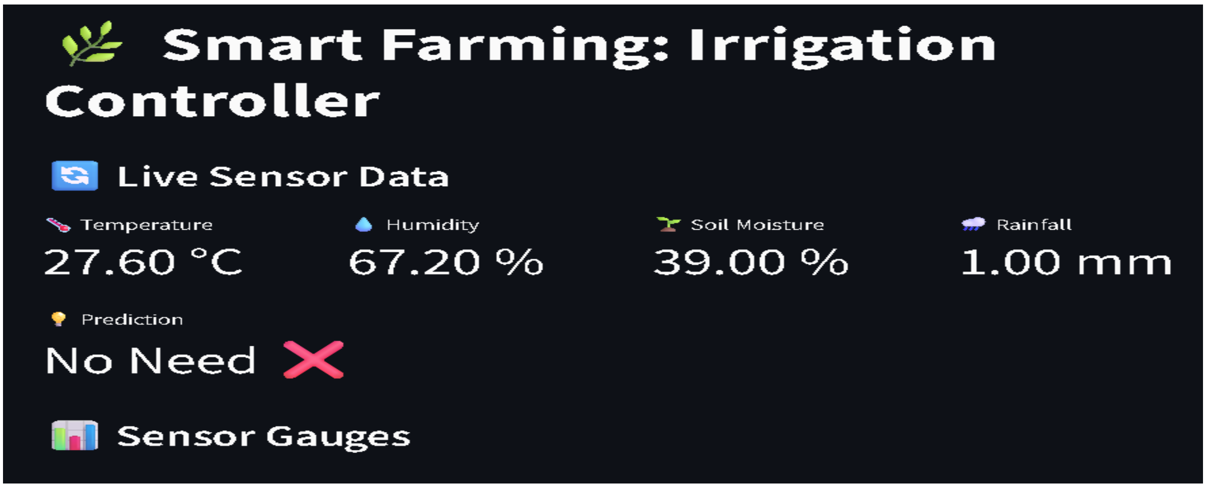


Figure 1. This is a web dashboard where we can see the data from the backend integration

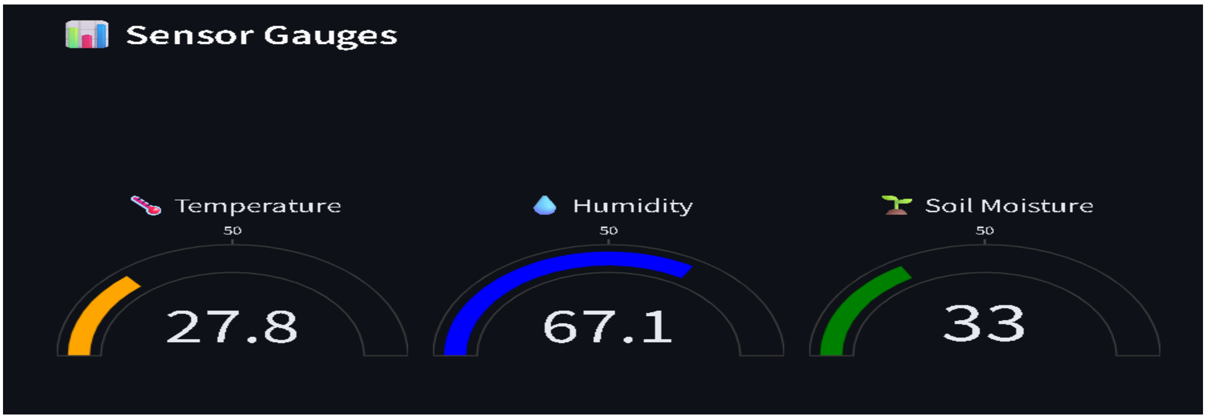


Figure 2. Sensor Gauges

VI. INTEGRATION OF AI/ML

In this section, we will present the AI/ML that enhances our irrigation system, which is a rule-based logic for decision-making techniques. This irrigation is improving our system for accuracy by using some patterns and relationships in historical and real-time databases. The proposed AI/ML enhancement involves several key steps:

a. Continuous Data Collection: Gather labeled datasets including soil moisture, temperature, humidity, rainfall, and irrigation outcomes over time to train models effectively.

b. Feature Engineering: Extract informative features such as moving averages of soil moisture and temperature, seasonal trends, and interaction effects among parameters to better capture environmental dynamics.

c. Model Training: In this section, we will use Random Forest for classifying data, Support Vector Machine (SVM), or Logistic Regression to learn irrigation patterns from incoming sensor data to train the model.

d. Model Deployment: In this section, we can use serial communication for better accuracy in the model training to a .pkl file and load it into the FastAPI backend using libraries such as joblib or pickle. This enables on-demand inference with the live dataset.

An example Python snippet for loading a model and predicting irrigation need is shown below:

```
import joblib
model = joblib.load('irrigation_model.pkl')
prediction = model.predict([[temperature, humidity, soil_moisture, rainfall]])
```

This is an AI-powered decision support which expected the outperform static rule-based methods by adapting the diverse conditions and capturing subtable data patterns, leading to more efficient water use and optimized crop yields.

VII. RESULTS AND DISCUSSION

By initial testing of the proposed IoT-based model for a smart farming system, which reads exact real-time data from the environment, including temperature, humidity, soil moisture, and rainfall. Data was consistently updated every 3 seconds and correctly reflected multiple conditions in the controlled environment.
Irrigation decisions are based on a predefined working model for performance as expected output in critical scenarios when soil moisture levels were low and no rainfall was detected through the sensors, and the irrigation system was triggered for irrigation.

Key advantages of this system are reducing the water consumption by 30-40%, reducing waste, and promoting sustainability. Automation minimized labor costs, supporting labor-constrained farmers.

The entire solution was developed for low-cost and availability of hardware components, ensuring affordability and easy deployment for small and limited farmers. To enhance its practicality in rural areas, the system is designed where internet connectivity is low or with limited range. The system is integrated with mobile app and web-based dashboard for visualization, enabling remotely navigating and controlling irrigation activities. This feature presents benefits for farmers who are not present in the field all the time and manage irrigation from a distance. Overall, this system is proposed for cost-effective, addressing key challenges related to accessibility, labor constraints, and resource efficiency.

VIII. CONCLUSION

This paper is presents a practical and low-cost IoT-based smart farming system that integrates Arduino sensors, Firebase is a cloud storage, and a Streamlit dashboard for real-time remote crop monitoring and automated irrigation system. This framework enables small-scale farmers to efficiently observing the environment data—such as soil moisture, temperature, humidity, and rainfall data—and make prompt irrigation decisions that conserve water and enhance crop yield.

By automating irrigation control based on live sensors data, where the irrigation system significantly reduces water wastage and minimizes manual labors. This is affordability for small type farmers and ease of deployment make it especially suitable for resource-constrained agricultural contexts.

Future work will focus on integrating AI/ML models to improve irrigation prediction accuracy, adding mobile notification systems for instant alerts, and scaling the framework to accommodate larger farming operations. Collectively, these enhancements will further increase system robustness, usability, and impact, promoting sustainable agriculture through advanced digital technologies.

IX. REFERENCES

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