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IoT Based Smart Irrigation System with Environmental Sensing and Monitoring

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***Abstract*—The demand for practicing agriculture efficiently day by day has become a great motivation to shift the culture of agriculture from traditional to automated. In the traditional agricultural system, it is a physical effort and time consuming to take care of the crops. The cultivation of crops, as well as other plants, is totally dependent on the environment. So for a good cultivation, farmers should have the knowledge about the environment for which weather monitoring is a prior demand. This IoT-based system lets cultivation have an extension of automation. The extensions that this system provides are monitoring the soil moisture, temperature, and humidity in real time. In addition, it provides an autonomous irrigation system that is real-time controlled. Overall, this system aims to optimize water usage, enhance crop monitoring and reduce manual intervention in irrigation practices.**

Keywords: Weather Monitoring, Smart Irrigation, IoT, Visual Insights, Automated Green House

I. Introduction

Agriculture is a fundamental cornerstone of global sustenance and economic stability, playing a critical role in ensuring food security and promoting sustainable development. Water is the most vital input in agriculture, and its efficient use has considerable implications for crop yield, resource conservation, and overall environmental health. In many regions, traditional irrigation practices—often reliant on manual observation and judgment—lead to inconsistent water management, resulting in either water wastage or insufficient irrigation [1]. These conventional techniques not only demand extensive labor and time but are also prone to errors that can adversely impact soil health and productivity.

Conventional irrigation methods typically involve manual monitoring of environmental parameters such as soil moisture, temperature, and humidity. This labor-intensive approach is increasingly becoming unsustainable in the face of rising water scarcity and expanding agricultural demands. Recent advancements in the Internet of Things (IoT) offer promising alternatives by integrating sensor technology with automated control systems. In contrast to traditional systems, IoT-based smart irrigation enables real-time monitoring and precise water management through automated decision-making processes [2]. By employing devices such as the ESP32 microcontroller and a variety of sensors, our proposed system can continuously assess field conditions and activate irrigation only when necessary, thereby optimizing water usage and enhancing crop productivity.

This study presents an IoT-driven smart irrigation system designed to overcome the inefficiencies of conventional farming practices. The system incorporates several key components: a suite of environmental sensors for real-time data acquisition, a relay-operated water pump for automated irrigation and a water level indicator for monitoring supply. The main contributions of this research are as follows:

- Introducing an automated irrigation system that integrates IoT-based sensors for precise water management, thereby reducing manual intervention.
- Demonstrating the effectiveness of automated environmental monitoring in optimizing water usage and enhancing crop yield.
- Evaluating system performance through real-world experiments and comparing it with traditional irrigation approaches.
- Providing a scalable framework that can be easily adapted for various types of crops and farming conditions.
- System reduces water use by preventing overwatering — saving up to 30–40 percent compared to manual methods.

II. Literature Review

The integration of the Internet of Things (IoT) in agriculture has received considerable attention over recent years for its potential to revolutionize farm management through automation and real-time monitoring. Numerous studies have investigated various aspects of IoT-based agricultural systems, focusing particularly on environmental sensing, remote control of irrigation, and efficient resource management.

Suma et al. [3] introduced an IoT-based smart agriculture monitoring system that employs an array of sensors to monitor key environmental parameters—such as soil moisture, temperature, and humidity. Their system facilitates automated irrigation, significantly reducing manual intervention while promoting efficient water use. In addition, the system incorporates a cloud-based data management platform that supports real-time remote monitoring and control of farm operations.

Similarly, Jain and Kumar [4] developed a comprehensive smart agriculture framework that integrates soil moisture and temperature sensors with an automated irrigation mechanism, triggered by real-time sensor data. Their approach leverages mobile technologies to enable remote monitoring, thereby enhancing farmers' decision-making capabilities and overall resource management.

In another study, Mini et al. [5] proposed an IoT-based monitoring solution that integrates multiple low-cost sensors for real-time environmental data collection. Their design includes an automated irrigation system controlled via a relay module—activated by specific soil moisture thresholds. The modular architecture of this system underscores its adaptability for various scales of agricultural operations, ranging from small farms to large estates.

Rajesh et al. [6] further demonstrated the scalability of IoT applications in agriculture by developing a system that utilizes a wireless sensor network to monitor environmental conditions continuously. The collected data is transmitted to a central processing unit, which then controls irrigation and other farm activities, thereby optimizing resource usage and reducing labor dependency across diverse farming environments.

Nuvvula et al. [7] explored the synergy between IoT and cloud computing for enhanced environmental monitoring in agriculture. Their work emphasizes the role of cloud-based platforms in handling large volumes of data from distributed sensor nodes and in facilitating predictive analytics through machine learning algorithms. This architecture not only enables remote monitoring but also empowers farmers to anticipate future environmental conditions and adjust their practices accordingly.

Collectively, these studies underscore the transformative potential of IoT in creating efficient, data-driven agricultural systems. However, while existing solutions excel in soil moisture monitoring, irrigation control, and remote surveillance, unlike many existing irrigation systems that rely solely on local control or basic automation, this project integrates real-time environmental monitoring with IoT-based remote control using the Blynk platform. It combines soil moisture, temperature, humidity, and water level sensing with both manual and automated pump control, including intelligent event-driven notifications. The system is designed to be scalable, low-cost, and adaptable, making it suitable for diverse farming conditions. Its ability to alert users proactively and conserve water through threshold-based logic distinguishes it from conventional approaches.

III. Methodology

The proposed IoT-based smart irrigation system leverages state-of-the-art sensing, data processing, and actuation techniques to automate irrigation, environmental monitoring, and greenhouse climate control. This section describes the system architecture, component functionality, data flow, control strategies, and future enhancements. Extensive experiments and literature studies have validated the design.

A. System Overview

The system comprises multiple sensor nodes, a central processing unit (ESP32), and various actuators integrated into a closed-loop control system. Its core functionalities include:

- **ESP32-Based Control Unit:** Acts as the central hub, collecting data from sensors and controlling the water pump.

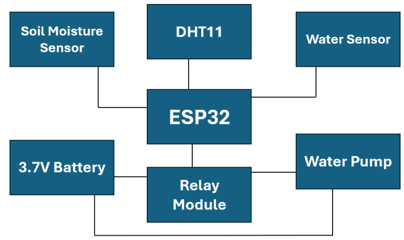

Fig. 1. IOT Based Smart Irrigation System

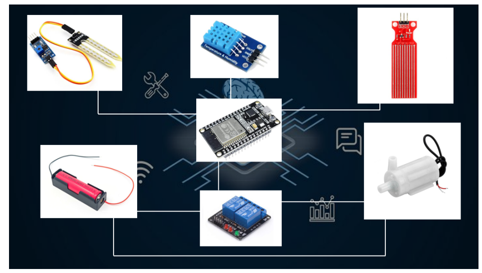

Fig. 2. IOT Based Smart Irrigation System

- **Integrated Sensors:** Uses soil moisture, temperature, humidity, and water level sensors to monitor environmental conditions.
- **IoT Connectivity via Blynk:** Real-time data visualization and remote control through the Blynk app using Wi-Fi.
- **Automated Irrigation:** The system automatically turns the water pump on/off based on soil moisture thresholds.
- **Smart Notifications:** Sends event-based alerts (e.g., high temperature, low moisture) to notify users of critical conditions.
- **Manual Override and Scalability:** Provides manual pump control through the app and is scalable for use in various farm setups.

Wireless data transmission to a cloud platform enables remote decision-making and management of the agricultural process [5].

B. Components and Functionalities

The system integrates a range of sensors and actuators that are described as follows:

TABLE I
Component Weight Summary

Component	Weight (g)
ESP32 Module	20
Soil Moisture Sensor	10
Temperature/Humidity Sensor	8
Water Level Sensor	9
Relay Module	15
Water Pump	200
3.7V Battery	250

1) ESP32 Microcontroller: The ESP32 serves as the system's central processor. It reads data from the sensors, processes it using predefined logic, and communicates with the cloud platform via Wi-Fi. The device's energy efficiency and connectivity are particularly well-suited for remote agricultural applications [8].

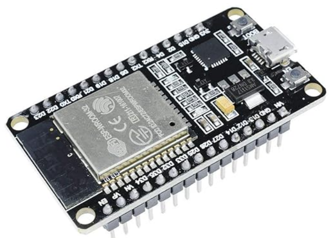

Fig. 3. ESP32

2) Soil Moisture Sensor: The soil moisture sensor continuously measures the water content in the soil. Its analog output is converted to digital signals by the ESP32's analog-to-digital converter (ADC). When the moisture level falls below a predetermined threshold, the system triggers the irrigation process. Calibration of the sensor ensures accuracy and optimal water utilization [9].

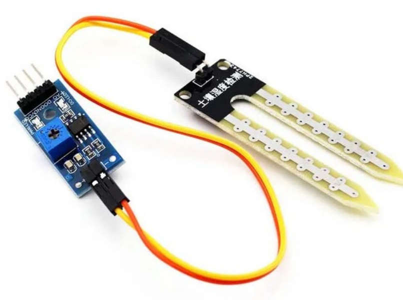

Fig. 4. Soil Moisture Sensor

3) Temperature and Humidity Sensors: These sensors record ambient temperature and humidity levels in both the field and greenhouse. The collected environmental data informs adjustments to the irrigation schedule and helps regulate the greenhouse climate by modulating the roof's position [10].

4) Water Level Sensor: The water level sensor monitors the availability of water in the reservoir. It is powered intermittently by the ESP32 to conserve energy and extends the sensor's lifespan. The analog readings are converted via the ADC and interpreted as percentage levels. When water falls below a safe operating threshold, a warning is issued through the cloud platform to prompt refilling [11].

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waterPercent = (waterRaw / 2000.0) * 100.0;
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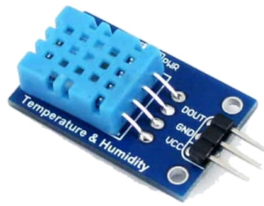

Fig. 5. Caption

Fig. 6. Water Level Sensor

5) Relay Module: The relay module acts as a digital switch, interfaced with the ESP32 microcontroller to control the flow of current to external devices such as the water pump. Operated through a GPIO pin, the relay is activated when the soil moisture drops below a predefined threshold or manually via the Blynk app. It ensures electrical isolation between the low-voltage control circuit and the high-voltage pump circuit, improving safety and reliability in the system's operation [12].

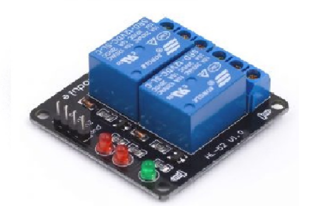

Fig. 7. Relay Module

6) Water Pump: The water pump is the primary actuator in the irrigation process. Powered by a 3.7V battery and controlled via the relay module, the pump is responsible for delivering water from the reservoir to the crops. It is activated automatically based on soil moisture data or manually through the Blynk app interface. The system ensures optimal usage of water by switching off the pump once the soil moisture exceeds the target threshold, thereby conserving energy and water resources [13].

Fig. 8. Water Pump

7) 3.7V Battery Power Supply: A 3.7V lithium-ion battery serves as the portable power source for the entire system. This low-power setup is crucial for deployment in remote agricultural zones where grid access is limited. The energy-efficient design of the ESP32 and power gating strategies for sensors and peripherals maximize the battery's lifespan, ensuring long-term autonomous operation [14].

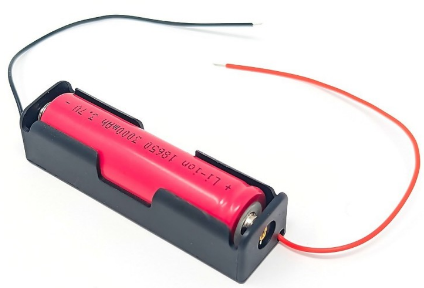

Fig. 9. 3.7 Battery

8) Blynk IoT Application: The Blynk app provides a user-friendly interface for real-time monitoring and control of the irrigation system. Sensor data such as soil moisture, temperature, humidity, and water level are displayed on virtual dashboards. Additionally, users receive notifications for critical conditions and can manually override the pump operation. Blynk's cloud integration facilitates seamless data communication and remote access [15].

C. System Design and Implementation

The system is designed as a closed-loop architecture that integrates real-time environmental sensing, autonomous control, and remote monitoring using IoT technology. The ESP32 microcontroller functions as the core processing unit, enabling data acquisition, decision-making, and actuation.

1) Sensing and Data Collection: The ESP32's analog-to-digital converters (ADC) collect readings from soil moisture and water level sensors, while temperature and humidity data are obtained via a DHT11 sensor. These values are periodically sampled and formatted for transmission. Sensor data is sent over Wi-Fi to the Blynk IoT platform for real-time visualization and logging, enabling users to monitor field conditions from any location.

2) Data Processing and Decision-Making: A lightweight decision-making algorithm on the ESP32 compares real-time sensor readings with predefined thresholds. For instance, if the soil moisture falls below 30 percent, or if the water level is critically low, appropriate actions such as triggering the water pump or sending alerts are initiated. In cases where soil moisture reaches 75

3) Actuation and Control: The ESP32 controls a relay module that switches the 3.7V-powered water pump. This ensures precise and automated irrigation only when needed. Additionally, users can override or initiate manual pump control remotely through a virtual button on the Blynk app, giving flexibility and user intervention when necessary.

4) Remote Monitoring and Feedback Loop: All sensor readings and system states are displayed on a mobile interface using the Blynk platform. Automated notifications are triggered if environmental parameters exceed or fall below safe thresholds (e.g., high temperature, low water level). This real-time feedback loop allows the system to adjust dynamically and keep users informed at all times.

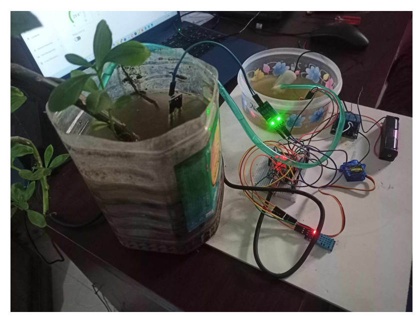

Fig. 10. IoT Based Smart Real-time Monitoring and Irrigation System

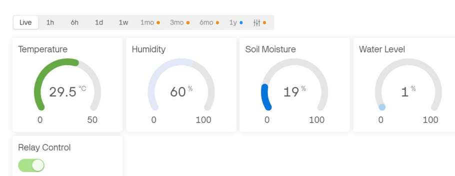

Fig. 11. Blyuk Data

D. Challenges and Future Enhancements

Although the system effectively demonstrates a low-cost, smart agriculture solution, several challenges and future improvements have been identified:

- **Power Limitations:** Continuous operation with a 3.7V battery poses constraints. Incorporating energy harvesting methods like solar panels can enhance sustainability.
- **Connectivity Dependence:** Reliance on Wi-Fi may restrict deployment in remote areas; future versions could support LoRa or GSM for broader coverage.
- **Sensor Expansion:** Integration of additional sensors such as pH, soil nutrients, or ambient light could offer more holistic environmental monitoring.
- **Data Intelligence:** Incorporating machine learning algorithms could help predict irrigation needs based on patterns and historical trends.
- **Modular Design:** Making the system modular would allow easy customization for different crop types and farm sizes.
- **Rugged Hardware Enclosure:** Protecting the hardware against dust, water, and temperature extremes would improve field robustness and reliability.

The current system lays the groundwork for scalable, smart agricultural solutions, and further enhancements aim to improve reliability, intelligence, and adaptability to various farming environments.

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