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ESP32 Based Smart Farming System

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ABSTRACT

Agriculture is increasingly challenged by inefficient resource utilization, climate variability, and the growing demand for sustainable food production. To address these issues, this project presents the design and implementation of an ESP32-based smart farming system that enables real-time monitoring and automated control of key agricultural parameters. The proposed system integrates multiple sensors to measure soil moisture, ambient temperature, humidity, light intensity, and water availability. The ESP32 microcontroller acts as the central processing unit, collecting sensor data and transmitting it wirelessly to a cloud-based or mobile application platform for remote visualization and control.

Based on predefined threshold values, the system automatically activates irrigation mechanisms through relay-controlled pumps, ensuring optimal soil moisture while minimizing water wastage. Users are also provided with manual control options through a mobile interface, enhancing flexibility and usability. Experimental observations indicate improved water efficiency, reduced manual intervention, and better crop environmental conditions compared to conventional farming practices.

The system is designed to be low-cost, scalable, and energy-efficient, making it suitable for small farms, greenhouses, and precision agriculture applications. By promoting intelligent irrigation and continuous environmental monitoring, the proposed solution contributes to sustainable agriculture and efficient resource management, aligning with modern smart farming and IoT-based agricultural practices.

Keywords : - ESP32 Microcontroller, Smart Farming System, Internet of Things (IoT), Automated Irrigation, Soil Moisture Monitoring

1. INTRODUCTION

This project focuses on the development of an ESP32-based smart farming system that provides automated monitoring and control of essential agricultural parameters. The ESP32 microcontroller is chosen due to its low cost, high processing capability, and built-in Wi-Fi connectivity, making it well suited for IoT applications. The system uses various sensors to observe environmental conditions and controls devices such as water pumps and other actuators through relay modules based on predefined threshold values. Sensor data is transmitted wirelessly to a mobile or web-based interface, allowing farmers to monitor and manage their farms remotely.

Automated Irrigation Control System

The automated irrigation mechanism is designed to optimize water usage by supplying water only when required. Based on predefined threshold values or sensor feedback, the ESP32 activates the irrigation pump through a relay module. This automation prevents over-irrigation and under-irrigation, both of which negatively affect crop health. The system also supports manual override, allowing farmers to control irrigation remotely when necessary.

IoT-Based Remote Monitoring and Control

The smart farming system utilizes IoT platforms to display real-time sensor data on a mobile or web-based interface. Farmers can monitor environmental conditions, irrigation status, and system alerts from anywhere using an internet- connected device. This remote accessibility reduces the need for constant physical supervision and improves response time to changing field conditions, making farming operations more efficient and convenient.

2. LITERATURE SURVEY

Correa-Quiroz et al. developed an ESP32-based smart drip irrigation and climate monitoring system for greenhouse environments. Their system used soil moisture, temperature, and humidity sensors with cloud-based monitoring to automate irrigation. Experimental results showed reduced water consumption while maintaining optimal growing conditions, highlighting the effectiveness of IoT-based automation in agriculture.

Adekunle and Abioye proposed a low-cost smart irrigation system using soil moisture sensors and microcontrollers to control water pumps automatically. Their work demonstrated that sensor-based irrigation significantly reduces water wastage compared to traditional manual methods, though it relied mainly on threshold-based control rather than intelligent decision-making.

Several studies have explored the integration of wireless sensor networks (WSN) and renewable energy sources for smart farming. Capcha-Ochoa et al. introduced a solar-powered IoT irrigation system that improved scalability and sustainability in remote agricultural areas. However, most decision-making processes were cloud-dependent, leading to latency and higher power consumption.

More recent research has incorporated artificial intelligence and edge computing into smart irrigation. An AI- integrated smart irrigation system using ESP32 and LoRa demonstrated that deploying lightweight machine learning models on the ESP32 enables real-time irrigation decisions without constant cloud connectivity. This approach reduced latency, improved energy efficiency, and achieved significant water savings while maintaining optimal soil moisture levels.

3. SMART FARMING SOLUTION USING ESP32 AND IOT FOR EFFICIENT RESOURCE MANAGEMENT

Smart farming is an emerging approach that utilizes modern technologies to enhance agricultural productivity while minimizing resource wastage. The integration of the Internet of Things (IoT) with embedded systems enables efficient monitoring and control of farming operations. This project presents a smart farming solution based on the ESP32 microcontroller, aimed at optimizing the use of water, energy, and labor through automation and real-time monitoring. The system employs multiple sensors to measure key environmental parameters such as soil moisture, temperature, humidity, and light intensity, with data transmitted wirelessly using the ESP32's built-in Wi-Fi capability to a cloud or mobile-based platform for remote access. Automated irrigation is achieved by activating a water pump through a relay module when soil moisture falls below a predefined threshold and deactivating it once optimal levels are reached, thereby preventing over-irrigation and water loss, while manual control is also provided for user flexibility. Designed to be cost-effective, scalable, and energy-efficient, the system is suitable for small- scale farms, greenhouses, and smart gardening applications, contributing to reduced manual intervention, improved crop monitoring, and sustainable resource management in precision agriculture.

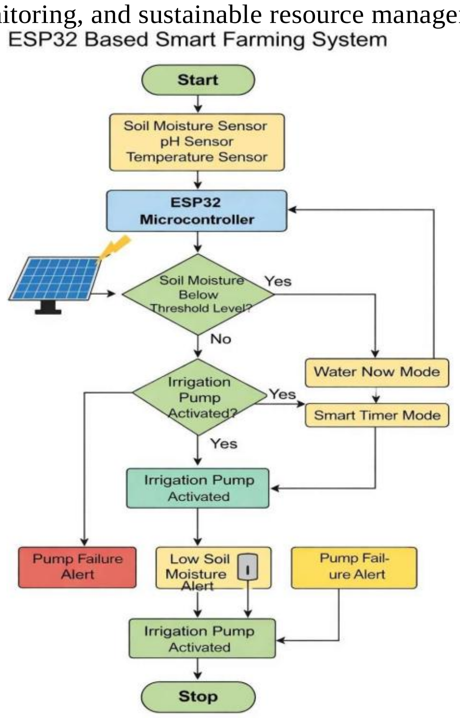

Fig -1: ESP32 Based Smart Farming System

3.1 Real-Time Environmental Monitoring and Automated Irrigation System

The Real-Time Environmental Monitoring and Automated Irrigation System is a smart agricultural solution designed to improve water management and crop productivity. Traditional irrigation methods often depend on fixed schedules and manual control, which can result in excessive water usage or insufficient irrigation. This system overcomes these limitations by using sensors and automation to make irrigation decisions based on actual environmental conditions.

3.2 An IoT-Based Approach for Sustainable and Precision Agriculture

An IoT-based approach to sustainable and precision agriculture focuses on using smart devices and connected technologies to improve farming efficiency while conserving natural resources. Precision agriculture aims to apply the right amount of water, fertilizers, and pesticides at the right time and place. By integrating Internet of Things (IoT) technology, farmers can monitor field conditions in real time and make data-driven decisions.

- Environmental Sensors
- IoT Communication Network
- Data Analytics and Cloud Storage
- Automated Control Systems

4. METHODOLOGY AND SYSTEM IMPLEMENTATION

The development of the proposed system followed a structured methodology encompassing component selection, circuit design, algorithm development, and system integration. The ESP32 microcontroller serves as the central processing unit, coordinating data acquisition, decision-making, and communication tasks. Environmental sensors were selected based on accuracy, reliability, and compatibility with embedded platforms

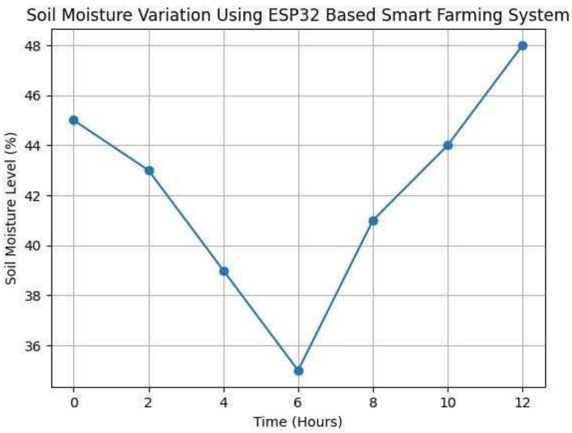

Fig -2: Soil Moisture Variation

4.1 Environmental Sensing and Actuation Components

A capacitive soil moisture sensor is employed to assess soil water content without the corrosion issues associated with resistive probes. Ambient temperature and humidity are monitored using a digital sensor, while ultraviolet radiation is measured to account for solar exposure within the greenhouse. An ultrasonic sensor monitors the water level in the storage tank to prevent pump dry-running. A relay module controls the irrigation pump, and an LCD provides local visualization of system status.

4.2 Hybrid Control Algorithm for Irrigation Management

The control algorithm operates in automatic and manual modes. In automatic mode, irrigation decisions are made based on sensor thresholds, whereas manual mode allows user-driven control through the cloud interface. This hybrid control strategy enhances adaptability to varying operational requirements

5. CONCLUSIONS

This study developed an IoT-based smart drip irrigation and climate monitoring system using the ESP32 microcontroller. The system combines environmental sensors, cloud monitoring, and automatic as well as manual control to improve water efficiency in greenhouse environments. Experimental results show that the proposed approach reduces water consumption while maintaining optimal growing conditions. Its modular design allows easy expansion and future integration with renewable energy and intelligent prediction techniques for improved irrigation management.

6. REFERENCES

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