DESIGN AND IMPLEMENTATION OF INTERNET OF THINGS ENABLED SMART AGRICULTURAL SYSTEM

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Abstract: This paper presents the design and implementation of an IoT-enabled smart agriculture system designed to enhance traditional farming practices through real-time monitoring of environmental parameters. The system integrates multiple sensors to measure temperature, humidity, soil moisture, and pH levels. Utilizing the Blynk IoT platform, the system provides real-time data visualization, enabling farmers to make informed decisions about irrigation and soil management. The project consists both hardware and software development, including rigorous testing of individual components and the integrated system. The DHT11 sensor demonstrated stable temperature and humidity measurements within a 2% deviation from reference instruments. The soil moisture sensor showed high sensitivity to changes in soil water content, ensuring precise irrigation management, while the pH sensor delivered accurate readings consistent with a standard pH meter. This project demonstrates the significant potential of IoT technology in revolutionizing agriculture and underscores the viability of IoT solutions in promoting smarter, more efficient agricultural practices.

Keywords: Internet of Things, Sensors, Temperature, Humidity, Soil moisture, Soil pH, Microcontroller

Introduction

Agriculture has long been regarded as one of the most essential sectors in human history since it provides humans with necessary resources, such as food, fiber, and energy. Using modern technology, such as the Internet of Things (IoT), the agriculture industry could be further enhanced. IoT-based smart agriculture systems are increasingly transforming the way agriculture goods are produced, not just by making it better but also by increasing its efficiency and reducing waste (Chinedu *et al*., 2022). Smart agriculture, also known as precision agriculture or digital farming, refers to the use of advanced technologies and data-driven approaches to optimize agricultural practices and increase productivity, efficiency, and sustainability in farming operations. This includes the integration of various technologies such as the Internet of Things (IoT), sensors, drones, artificial intelligence (AI), robotics, and data analytics to monitor and manage crops, soil, water usage, livestock, and other factors affecting agricultural production. Smart agriculture aims to enable farmers to make data-driven decisions, optimize resource utilization, minimize environmental impact, and enhance overall agricultural performance, ultimately leading to improved crop yields, profitability, and food security. Smart farming combines different technologies, devices, protocols, and computing paradigms to enable farmers to make the most out of innovations. Innovations in agriculture are called the "*digital agricultural revolution*" and will transform all aspects of agriculture, resulting in more productive, efficient, sustainable, inclusive, transparent, and resilient systems (de Araujo Zanella et al., 2020). By designing and implementing an Internet of Things (IoT) smart agriculture powered by microcontroller, this project hopes to contribute to the advancement of IoT-based smart agriculture, demonstrate the potential of this technology for various applications, and inspire further research in the field.

Review of Similar Works

Pratihar *et al.* (2020) proposed a Smart Agriculture Monitoring and Irrigation System using IoT to address challenges like unplanned water usage in large agricultural fields. The system utilizes microcontrollers (Atmega8 and Node-MCU) interfaced with DS18B20 soil temperature and FC28 soil moisture sensors to monitor environmental parameters. Sensor data is uploaded to a server, allowing farmers to monitor soil conditions and control water sprinkling via a motor pump based on soil temperature. This efficient water management solution minimizes wastage without burdening farmers. While effective for temperature, humidity, and moisture monitoring, the system could benefit from integrating soil pH measurement to provide a more comprehensive assessment of soil health and crop growth potential.

Rajesh *et al.* (2020) proposed an IoT-based agriculture monitoring system that uses wireless sensor networks to collect and transmit data from various sensors deployed on a farm. The system addresses critical agricultural challenges like heavy rainfall, temperature variations, and animal intrusion by allowing farmers to monitor field conditions remotely via mobile phones and receive SMS alerts. Sensors such as DHT11 for temperature and humidity, a PIR sensor for motion detection, and a soil moisture sensor collect data processed by a microcontroller. If thresholds are exceeded, actions like temperature regulation or alerts are triggered. The system updates data on the ThingSpeak IoT platform every 15 seconds, providing real-time information and visualizations. However, the developed system utilizes a mobile hotspot module for farmer access, offering a more accessible and versatile solution, especially in areas with unreliable or no network connectivity.

Mini *et al.* (2023) proposed an IoT-based smart agriculture monitoring system that senses temperature, humidity, and soil moisture levels and transmits this data to an IoT platform, helping farmers optimize resource use and prevent crop loss. Powered by rechargeable Lithium-ion batteries, the system uses an Arduino Nano and ESP32 microcontroller, and it connects to a mobile application via Bluetooth for real-time monitoring. Farmers can remotely access accurate data on field conditions, reducing labor and improving decision-making. While the system effectively monitors key parameters, it omits soil pH monitoring, which is vital for assessing soil health and nutrient availability for optimal crop growth.

Suresh Kumar *et al.* (2023) proposed an IoT and Android-based system designed to monitor soil moisture levels and alert farmers when plants need watering. This system addresses agricultural challenges like inefficient water use, poor soil quality, and unpredictable weather conditions that affect crop yield and profitability. The system uses moisture sensors to detect soil moisture levels and measures temperature and humidity. If the soil moisture falls below a set threshold, it automatically triggers water release to maintain optimal moisture levels. Farmers can also control irrigation via an Android app, adjusting water levels according to crop requirements. The IoT-based solution helps predict soil moisture and humidity, enabling efficient irrigation management, minimizing labor, and promoting smart farming practices. While the system typically relies on an internet connection for functionality, The developed system offers an alternative through mobile hotspot connectivity, ensuring continued operation even in remote areas with limited or unreliable internet access.

Chinedu *et al*. (2022) developed an IoT-based Smart Agriculture Monitoring System that enhances farm productivity by automating the monitoring of key environmental factors like pH, humidity, temperature, and soil moisture. Utilizing sensors connected to an Arduino Uno microcontroller, the system collects real-time data and sends alerts via email or SMS when values fall outside predetermined thresholds. This approach minimizes labor, optimizes resource use, and streamlines agricultural practices. While internet access is required for data transmission, incorporating a GSM hotspot module could improve accessibility in areas with limited connectivity, making the system more versatile and reliable.

Materials and Methodology

This section details the materials and methods used in the design and development of an IoT-enabled smart agriculture system powered by a microcontroller.

Materials

The project utilized the following materials:

NodeMCU Microcontroller: Central processing unit based on ESP8266 with Wi-Fi capabilities.

LEDs, Sensors, Power Supply, Diodes, Resistors, Capacitors: Essential electronic components for system functionality.

7805 Voltage Regulator: Ensures stable voltage output.

Methods

Design Analysis and System Architecture

The IoT system integrates a NodeMCU microcontroller with sensors for humidity, temperature, soil moisture, and pH levels. The NodeMCU processes and transmits data wirelessly to user devices, facilitating real-time monitoring and decision-making. The architecture includes the microcontroller, sensors, a communication module, and a power supply.

Hardware Components and Working Principles

The design integrates several components:

NodeMCU Microcontroller: Manages data collection and communication.

Sensors: Measure environmental parameters (temperature, humidity, soil moisture, pH).

Power Supply: Converts AC to stable DC for system operation.

AC Source, Transformer, Bridge Rectifier, Capacitors, Voltage Regulator: Convert and regulate power to ensure stable operation.

System Development

Microcontroller Programming: Utilizes Arduino IDE to program the NodeMCU, handle sensor data acquisition, and enable data transmission.

Data Visualization: Blynk IoT platform is used to visualize sensor data on user devices, providing a comprehensive view of environmental conditions.

Component Integration: Detailed connections of power supply, sensors, and microcontroller are ensured for effective operation and data transmission.

Discussion of Results

The consistent and accurate performance of the DHT11 temperature and humidity sensor, soil moisture sensor, and pH sensor demonstrates their suitability for agricultural monitoring, as reliable data collection is crucial for effective farming decisions. Additionally, the successful integration of the NodeMCU microcontroller with these sensors and the Blynk IoT platform highlights the system's ability to seamlessly connect hardware and software components as shown in Figure 1 below. The system's robustness and lack of connectivity issues during testing confirm its efficiency in handling real-time data processing and transmission, ensuring a reliable foundation for agricultural management. Figure 2 shows sensor during components testing.

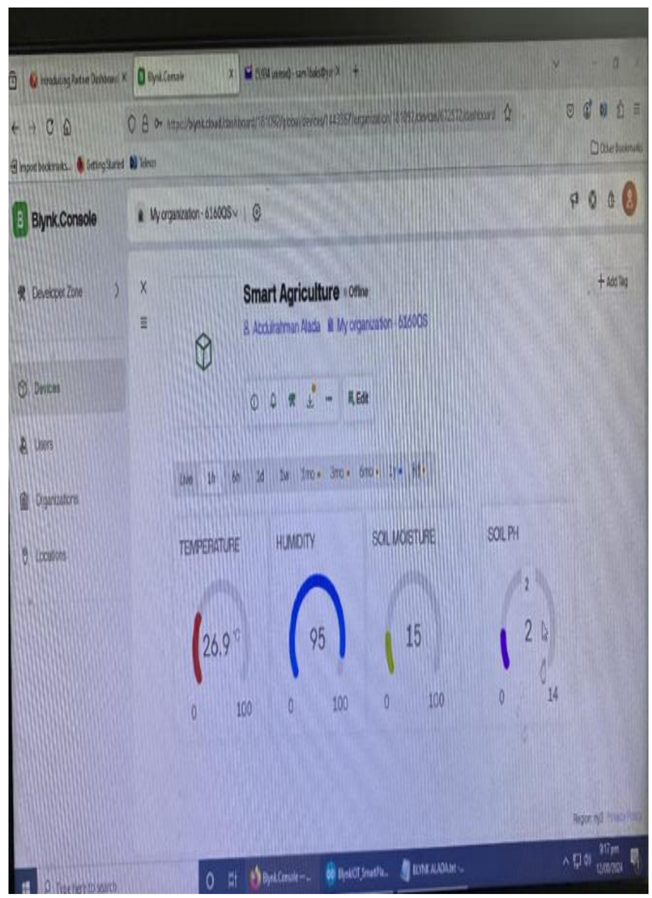

Figure1: Blynk Interface

Figure2: Sensor for component testing

The system's response time was quick, and it effectively handled real-time data updates. Power consumption was within expected limits, ensuring operational efficiency. Field tests on various soil types (sandy, loamy, and clay) revealed distinct soil characteristics. Figure 3 below shows performance testing on the three types of soil.

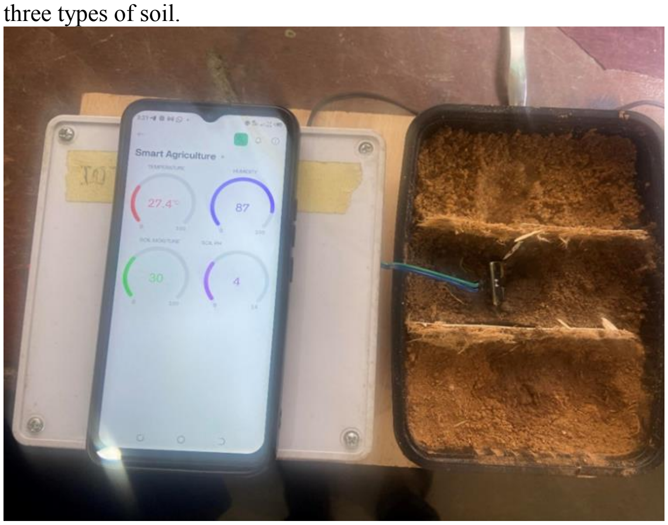

Figure3: Performance testing on the three types of soils

The table below shows average of results obtained from testing on the three types of soils.

Table 1: Characterization of soil sample

Soil Type	Humidity (%)	Temperature (°C)	Soil Moisture (%)	Soil pH
Sandy soil	87	27.8	39.6	1.8
Loamy soil	87	27.8	49.33	4.8
Clay soil	88	27.4	67.33	3.8

Testing across different soil types (sandy, loamy, and clay) revealed how each soil type reacts to varying water contents. The high-water retention in clay soil, the balanced characteristics of loamy soil, and the low retention in sandy soil provide valuable insights for farmers to tailor their irrigation and soil management strategies. These findings emphasize the importance of understanding soil characteristics to optimize agricultural practices.

Conclusion and Recommendations

The IoT-enabled smart agriculture system was successfully designed and developed to improve agricultural practices through real-time environmental monitoring. The system, incorporating various sensors, a NodeMCU microcontroller, and the Blynk IoT platform, demonstrated its capability to deliver accurate and reliable data in both controlled and field conditions. For future enhancements, research could focus on improving sensor accuracy by reducing external interferences, redesigning the system's structure and algorithms to accommodate additional functionalities, and exploring advanced technologies such as machine learning for predictive analytics and blockchain for secure data management.

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