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IoT Based Plant Health Monitoring System

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ABSTRACT
The Internet of Things (IoT) has revolutionized modern agriculture by enabling automation, remote monitoring, and efficient resource utilization. This paper presents an IoT- Based Plant Health Monitoring System that continuously monitors soil moisture, humidity, temperature, and water level conditions using smart sensors and wireless communication technologies. The proposed system uses Arduino Uno, NodeMCU ESP8266, DHT11 sensors, and soil moisture sensors for real-time monitoring and automated irrigation. Sensor data is uploaded to cloud platforms, allowing farmers to monitor agricultural conditions remotely through smartphones or computers. The proposed system minimizes water wastage, reduces manual labor, improves irrigation efficiency, and enhances crop productivity. Additionally, the system incorporates a buzzer- based alert mechanism to prevent crop damage caused by animal intrusion. Real-time telemetry data is synchronized with IoT cloud platforms, enabling remote monitoring and administrative control through smartphones and web interfaces. Experimental analysis demonstrates that the proposed system significantly optimizes water utilization and reduces manual intervention in agricultural operations.

Keywords: IoT, Smart Agriculture, NodeMCU, Arduino Uno, Soil Moisture Sensor, DHT11, Plant Health Monitoring.

1. INTRODUCTION

Agriculture is one of the most important sectors contributing to the economy of many countries, especially India. Traditional agricultural methods depend on manual monitoring and irrigation processes, which consume significant time, effort, and resources. Due to changing climatic conditions, water scarcity, and increasing population, there is a need for advanced farming techniques that improve productivity while conserving natural resources.

The integration of Internet of Things (IoT) technology with agriculture has introduced smart farming systems capable of automating agricultural operations. IoT enables communication between sensors, microcontrollers, and cloud platforms to provide real-time monitoring and control of environmental conditions. Smart agriculture systems help farmers make accurate decisions related to irrigation, fertilization, and crop management.

The integration of Wireless Sensor Networks (WSNs) with IoT technology enables efficient environmental monitoring and precision agriculture. Earlier systems relied on ZigBee and GSM communication modules, which suffered from higher deployment costs and limited scalability. Modern IoT architectures using Wi-Fi- enabled microcontrollers and cloud computing platforms provide cost-effective, scalable, and real- time agricultural monitoring solutions.

The proposed IoT-Based Plant Health Monitoring System continuously monitors environmental parameters such as soil moisture, temperature, humidity, and water level using sensors. Sensor data is processed by the Arduino Uno microcontroller and uploaded to cloud platforms through the NodeMCU ESP8266 module. Based on soil moisture conditions, the irrigation system is controlledautomatically.

The proposed system reduces human intervention and ensures proper water management. Farmers can remotely monitor crop conditions and receive updates through mobile applications or web interfaces. The system contributes significantly toward precision agriculture and sustainable farming practices.

2. OBJECTIVES OF THE SYSTEM

The main objectives of the proposed system are:

1. To monitor soil moisture, humidity, temperature, and water levels in real time.
2. To automate irrigation systems using sensor-based monitoring.
3. To reduce water wastage and improve irrigation efficiency.
4. To provide remote monitoring through cloud technology.
5. To improve crop productivity and reduce labour costs.
6. To create a cost-effective and scalable smart agriculture solution.

3. NEED OF SMART AGRICULTURE

Rapid population growth and decreasing agricultural resources require advanced farming solutions. Traditional irrigation methods often result in water wastage and inefficient crop management. Smart agriculture systems help optimize resource utilization and improve farming efficiency.

IoT-based monitoring systems provide accurate environmental data that enables farmers to make better decisions. Real-time monitoring helps identify crop diseases, soil deficiencies, and environmental changes effectively. Automation also reduces dependency on manual labor and improves operational efficiency.

Smart farming technologies contribute to sustainable agriculture by reducing excessive water usage and minimizing environmental impact. Cloud-based monitoring systems provide farmers with easy access to field data from remote locations.

4. LITERATURE REVIEW

Several researchers have explored IoT and Wireless Sensor Network (WSN)-based agricultural monitoring systems over the past decade. BalajiBanu et al. proposed a WSN-based agriculture monitoring framework using ZigBee communication for environmental data collection. However, the system faced reliability and communication limitations under harsh weather conditions.

Joseph Haule et al. developed an automated irrigation scheduling system based on real-time soil monitoring. Their research demonstrated improved irrigation efficiency but highlighted deployment and maintenance challenges in large-scale agricultural fields.

Dr. Sanjay Patil and MadhuriJadhav implemented a cloud-based smart irrigation system capable of remotely controlling water pumps through Android applications. Although the system improved automation, it lacked fault-tolerant backup mechanisms and advanced predictive monitoring features. The proposed system addresses these limitations by providing

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a low-cost, scalable, energy-efficient, and cloud-integrated smart agriculture monitoring solution

5. EXISTING SYSTEM

Traditional agricultural systems rely heavily on manual irrigation and observation techniques. These systems lack automation and remote monitoring capabilities. Irrigation is often performed without analysing soil moisture conditions, leading to excessive water consumption and poor water management. Some wireless sensor network-based systems are available, but they involve complex implementation procedures and high maintenance costs. Existing systems also suffer from low efficiency, limited scalability, and lack of real-time cloud connectivity features.

6. PROPOSED SYSTEM

The proposed system integrates Arduino Uno, NodeMCU ESP8266, DHT11 sensors, soil moisture sensors, water level sensors,relay modules, and water pumps to automate agricultural operations. Sensors continuously collect environmental data and send it to the microcontroller for processing.

When the soil moisture level falls below a predefined threshold value, the relay module activates the water pump automatically. Once sufficient moisture is detected, the water pump is turned OFF automatically. This process ensures efficient irrigation and prevents water wastage.

The NodeMCU ESP8266 module uploads sensor data to cloud platforms using Wi-Fi connectivity. Farmers can monitor environmental conditions remotely using smartphones or computers.

7. WORKING PRINCIPLE

The working principle of the system is based on sensor data acquisition and automation. Soil moisture sensors continuously monitor moisture levels in the soil and send data to the Arduino Uno microcontroller. If the moisture level falls below the threshold value, the relay module activates the water pump automatically. Once the required moisture level is achieved, the pump is switched OFF automatically. The DHT11 sensor continuously monitors environmental conditions such as temperature and humidity.

The DHT11 sensor communicates with the microcontroller using a single-wire digital communication protocol. The sensor transmits a 40-bit data frame containing humidity, temperature, and checksum information. Accurate timing pulses are used to synchronize communication between the sensor and the Arduino Uno microcontroller.

The proposed system operates through continuous sensor data acquisition and automated decision- making processes. Environmental sensors periodically collect data related to soil moisture, temperature, humidity, and water levels from the agricultural field. The Arduino Uno microcontroller processes the incoming sensor values and compares them with predefined threshold conditions stored within the system program.

The soil moisture sensor plays a major role in irrigation automation. When the soil becomes dry and the moisture level drops below the specified threshold value, the microcontroller activates the relay module to start the water pump automatically. As water is supplied to the soil, the moisture level gradually increases. Once the required moisture level is achieved, the

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relay module switches OFF the water pump to prevent excessive irrigation and water wastage.

The DHT11 sensor continuously monitors atmospheric temperature and humidity conditions. These environmental parameters help farmers understand climatic variations that may affect crop growth and soil conditions. Real-time environmental monitoring improves agricultural decision-making and enables better crop management practices.

The NodeMCU ESP8266 module provides wireless communication between the hardware system and cloud platforms through Wi-Fi connectivity. Sensor readings are transmitted periodically to IoT cloud dashboards where users can remotely monitor field conditions using smartphones, laptops, or web interfaces. The cloud platform also stores historical data for future analysis and monitoring purposes.

The integrated buzzer alert mechanism improves field protection by generating warning signals during animal intrusion or abnormal environmental conditions. This additional feature enhances agricultural safety and minimizes crop damage during unattended operation.

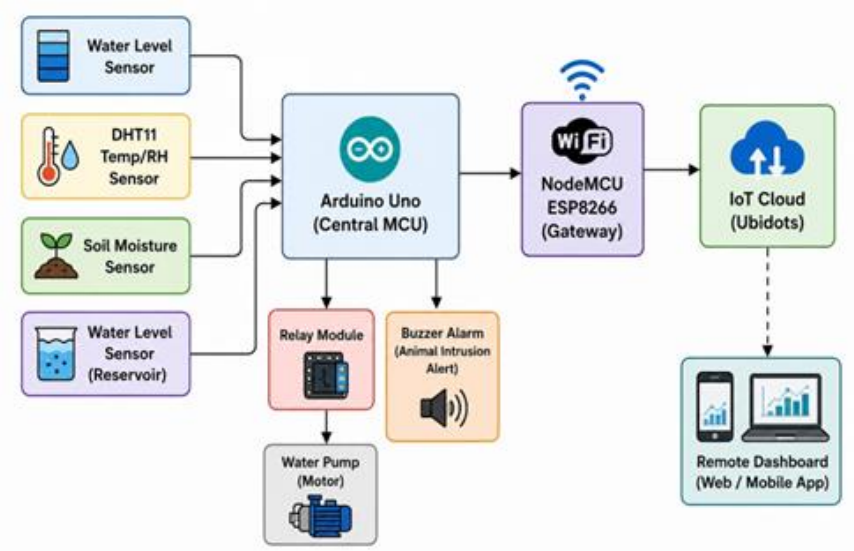
8. SYSTEM ARCHITECTURE

The proposed intelligent monitoring framework uses a two-tier architecture consisting of sensor nodes, edge controllers, and cloud communication modules. Environmental sensors continuously monitor soil moisture, temperature, humidity, and water levels. The Arduino Uno acts as the central processing unit responsible for local data acquisition and decision-making operations.

The NodeMCU ESP8266 module serves as a wireless gateway that uploads sensor telemetry data to cloud platforms through Wi-Fi communication. The relay module controls the water pump automatically based on predefined soil moisture

9. HARDWARE COMPONENTS

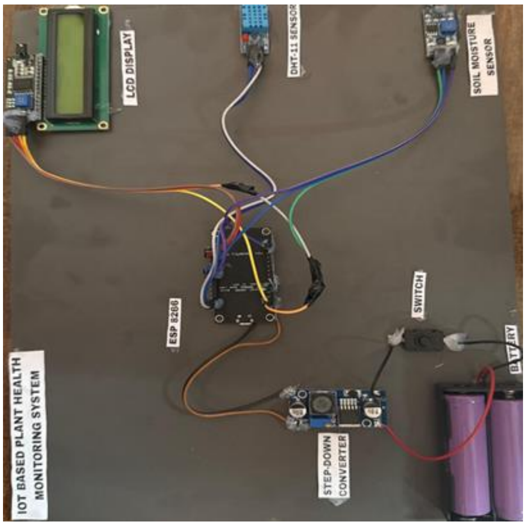
The hardware components used in the proposed system include:



Remote users can monitor field conditions through mobile or web dashboards connected to the cloud platform.

1. Arduino Uno – Main controller for processing sensor data.
2. NodeMCU ESP8266 – Provides Wi-Fi connectivity and cloud communication.

3. DHT11 Sensor – Measures temperature and humidity.
4. Soil Moisture Sensor – Detects moisture content in the soil.
5. Relay Module – Controls the water pump operation.
7. Water Pump – Supplies water automatically.
8. LCD Display – Displays real-time sensor data.



10. SOFTWARE IMPLEMENTATION

The software logic of the proposed system was developed using Embedded C programming language within the Arduino IDE environment. Sensor values are continuously monitored thanalong and digital input pins of the Arduino Uno microcontroller.
The logic framework is developed in Embedded C and deployed via the open-source Arduino IDE environment.

```
C
#include<Servo.h> // Includes core peripheral controls [cite: 636]
// PIN Mapping Definition constintsoilMoisturePin = A0; constintrelayMotorPin = 13;
constintbuzzerPin = 8;
constintdryThreshold = 1023; // Maximum threshold upon dry soil
void setup() { pinMode(soilMoisturePin, INPUT); pinMode(relayMotorPin, OUTPUT);
pinMode(buzzerPin, OUTPUT);
digitalWrite(relayMotorPin, LOW); // System initiates safely with pump off
}
void loop() {
intsensorValue = analogRead(soilMoisturePin);
// Closed-loop automation execution logic if (sensorValue>= dryThreshold) {
digitalWrite(relayMotorPin, HIGH); // Actuate relay to start pump
} else {
digitalWrite(relayMotorPin, LOW); // Turn off pump under optimal saturation
}
delay(2000); // Sampling interval synchronization delay
}
```

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The control algorithm compares real-time soil moisture readings with predefined threshold values. When dry soil conditions are detected, the relay module activates the water pump automatically. Cloud synchronization is achieved through HTTP- based communication protocols using the NodeMCU ESP8266 module.

The proposed IoT-Based Plant Health Monitoring System offers several advantages such as reduced water wastage, minimized labor costs, automated irrigation, improved crop productivity, and remote monitoring capabilities.

The system is energy-efficient, cost-effective, and scalable for various agricultural applications. Real- time monitoring enables efficient decision-making and improves overall farming productivity.

11. CLOUD IMPLEMENTATION

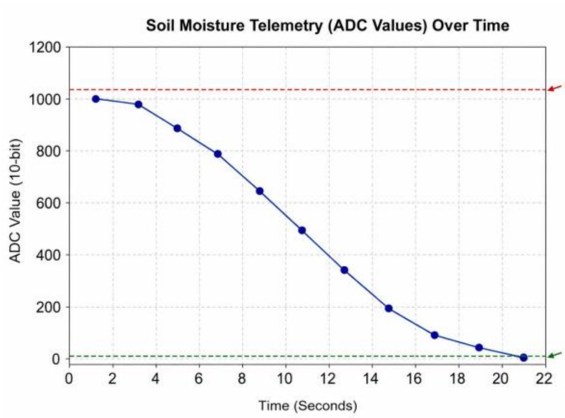
Telemetry metrics are streamed using the NodeMCU gateway over HTTP/HTTPS protocols to the Ubidots platform. Devices are automatically indexed into distinct tracking groups upon receiving data points matching unique system authorization tokens.

The remote cloud architecture uses a Synthetic Variables (SV) computation engine to calculate analytics for energy or water usage parameters:

$$\text{Synthetic Mean Optimization} =
\text{mean}(\text{current} \times \text{voltage},
\text{"w"})$

12. RESULT AND DISCUSSIONS

Before physical assembly, circuit reliability and load behaviours were verified using virtual prototype evaluations within the Proteus Virtual System Modelling (VSM) simulation engine. The simulation results demonstrated stable communication between the Arduino Uno and NodeMCU ESP8266 modules during continuous sensor monitoring operations. The relay switching mechanism responded accurately to varying soil moisture levels without noticeable delay or signal interruption. Sensor values obtained during simulation closely matched the expected environmental conditions, indicating reliable system performance.



Outdoor performance assessments confirmed that the closed-loop system acts with exceptional accuracy. When soil values match dry baseline states (≈ 1023), the system triggers the relay switch inside milliseconds to start irrigation. As moisture disperses across the testing zone, the recorded resistance drops steadily toward saturation parameters

13. FUTURE SCOPE

Future enhancements may include AI-based crop disease detection, machine learning algorithms for predictive analysis, drone-based crop monitoring systems, and automated fertilization techniques. Integration with solar-powered systems can further improve energy efficiency and sustainability.

Future improvements to the proposed system may include the integration of Artificial Intelligence (AI) and Machine Learning (ML) algorithms for predictive crop analysis and disease detection. Advanced data analytics techniques can be used to identify environmental patterns, predict irrigation requirements, and optimize agricultural productivity based on historical sensor data.

The system can also be enhanced using drone- assisted monitoring technologies for large-scale agricultural fields. Drone-based image processing and aerial surveillance can help detect crop diseases, pest infestations, and nutrient deficiencies more efficiently. Integration of computer vision techniques may further improve automated agricultural management systems. Future versions of the system may incorporate solar-powered energy management modules to improve sustainability and reduce dependency on conventional power sources.

14. CONCLUSION

The IoT-Based Plant Health Monitoring System provides an efficient solution for modern agriculture through automation and real-time monitoring. The integration of sensors, wireless communication, and cloud technology significantly improves irrigation efficiency and crop productivity.

The proposed system minimizes water wastage, reduces manual effort, and supports sustainable agriculture practices. Smart agriculture technologies will play a major role in future farming systems and environmental conservation.

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