

IOT-Based Design and Simulation of Smart Greenhouse Monitoring and Control System

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Abstract—Greenhouses Provide a controlled environment for plant cultivation, but traditional greenhouse management often depends on manual monitoring of environmental conditions such as temperature, humidity, soil moisture, and light intensity. This manual approach is time-consuming and may lead to inaccurate regulation of plant growth conditions. To address these challenges, this paper presents an IoT-based greenhouse monitoring and controlling systems that enables automatic observation and management of environmental parameters inside the greenhouse. The proposed system integrates multiple sensors including the DHT11 sensor for temperature and humidity measurement, a soil moisture sensor for detecting water content in soil, and an LDR sensor for measuring light intensity. These sensors are connected to an Arduino microcontroller, which acts as the central processing unit and continuously collects environmental data from the greenhouse.

The sensed data is transmitted to the cloud through the NodeMCU ESP8266 Wi-Fi module, enabling real-time monitoring using a smartphone or desktop device. The system also includes an automated control mechanism in which actuators such as fans, water pumps, and artificial lighting systems are activated whenever the environmental parameters exceed predefined threshold levels. This automated process helps maintain optimal conditions for plant growth without continuous human intervention. The implementation of this system reduces manual effort, improves monitoring accuracy, and ensures efficient environments. By integrating IoT

technology with greenhouse management, the system enhances crop productivity, resource efficiency, and sustainable agricultural practices.

Keywords: IoT, Arduino UNO, NodeMCU ESP8266, DHT11 Sensor, Soil Moisture Sensor, LDR.

I INTRODUCTION

Agriculture plays a vital role in human life and economic development. Greenhouses are controlled environments used for growing plants under suitable climatic conditions. The growth and productivity of plants mainly depend on environmental parameters such as temperature, humidity, soil moisture, and light intensity. In traditional greenhouse systems, these parameters are monitored manually by farmers. This manual monitoring requires continuous observation and experience, which may lead to errors and inefficient management of resources. To overcome these limitations, the Internet of Things (IoT) provides an effective solution for smart agriculture. IoT enables automatic monitoring and control of environmental conditions inside the greenhouse. In an IoT-based greenhouse monitoring system, different sensors are used to measure environmental parameters in real time. Sensors such as DHT11 temperature and humidity sensor, soil moisture sensor, LDR sensor for light intensity, and flame sensor are used to collect data from the greenhouse environment.

The collected data is processed by a microcontroller such as Arduino UNO, which acts as the central

controller of the system. The environmental data is transmitted to the cloud through the NodeMCU ESP8266 Wi-Fi module, allowing the user to monitor the greenhouse conditions remotely using a smartphone or computer. If any parameter exceeds the predefined threshold level, the system automatically activates the corresponding actuators.

For example, when the temperature exceeds the set limit, a fan is activated to reduce the temperature. If the soil moisture level decreases, a water pump is turned on to provide sufficient water to the plants. Similarly, when the light intensity is low, an artificial lighting system is activated to maintain proper light conditions inside the greenhouse.

This automated greenhouse monitoring and controlling system reduces human effort and minimizes manual errors. It also ensures optimal environmental conditions for plant growth, leading to improved productivity and efficient resource utilization. Such IoT-based systems are useful in plant nurseries, agricultural fields, and greenhouse framing, helping farmers manage multiple greenhouse remotely and efficiently.

II LITERATURE SURVEY

J. Seetaram, A. Bhavya, C. Tarun, and V. Sameera (2024) developed an IoT-based greenhouse monitoring and controlling system using an ESP32 microcontroller. In their work, different sensors such as temperature, humidity, and soil moisture sensors were installed inside the greenhouse to continuously collect environmental data. The collected sensor data is transmitted through Bluetooth to an IoT platform (MATLAB), which allows farmers to monitor greenhouse conditions remotely in real time. The system also includes automated control mechanisms where devices such as fans, irrigation pumps, and lighting systems are activated automatically when the sensed values cross predefined threshold levels. This approach helps maintain optimal environmental conditions for plant growth, reduces manual monitoring, and improves agricultural productivity through efficient resource management.

III OBJECTIVE

The main objective is to develop an intelligent IoT-based greenhouse monitoring and controlling system

that can continuously observe environmental conditions and automatically maintain suitable parameters for plant growth. The system aims to improve agricultural productivity by enabling real-time monitoring, automated control, and remote access to greenhouse data. The specific objectives of the proposed work are as follows:

- 1) To design and develop a smart greenhouse monitoring unit using an **Arduino microcontroller integrated with the NodeMCU (ESP8266) Wi-Fi module**.
- 2) To measure important environmental parameters such as **temperature, humidity, soil moisture, and light intensity** using suitable sensors
- 3) To continuously display the sensed environmental data through a **local monitoring interface** and transmit the data to an IoT cloud platform for remote observation.
- 4) To enable **real-time monitoring of greenhouse conditions through mobile phones or computers** using internet connectivity.
- 5) To implement an **automatic control mechanism** that activates actuators such as water pumps, fans, and artificial lighting whenever the sensor values cross predefined threshold limits.
- 6) To reduce the need for constant human supervision by introducing **automation in irrigation, ventilation, and lighting control**.
- 7) To improve plant growth conditions and agricultural productivity by maintaining an **optimal greenhouse environment**.

IV EXISTING METHOD

In existing greenhouse monitoring systems, environmental parameters such as temperature, humidity, soil moisture, and light intensity are monitored using different sensors. These sensors are connected to Arduino to collect and process the data. The system helps farmers to observe the environmental conditions inside the greenhouse

In some systems, wireless communication technologies such as Bluetooth or IoT platforms (MATLAB) are used to send the collected data to a smartphone or computer. This allows the user to monitor the greenhouse conditions remotely. Based on the sensor readings, devices like fans, water pumps, and lights can be turned ON or OFF automatically.

However, most of the existing systems mainly focus on basic monitoring and simple automation. They do not provide advanced features such as intelligent analysis, efficient energy management, or improved decision-making for better plant growth. Therefore, there is a need for a more efficient and reliable greenhouse monitoring system. Therefore, there is a need to develop a more efficient greenhouse monitoring system that can provide reliable monitoring, better automation, and improved environmental control for plant growth.

V PROPOSED METHOD

A. System Architecture Overview

The proposed intelligent energy meter consists of four functional layers: (1) sensing and measurement, (2) local processing and display, (3) cloud communication and logging, and (4) alerting and protection. The ESP32 microcontroller serves as the central hub interconnecting all layers. Figure 1 illustrates the overall block diagram of the proposed system. ^{16x2.LCD}

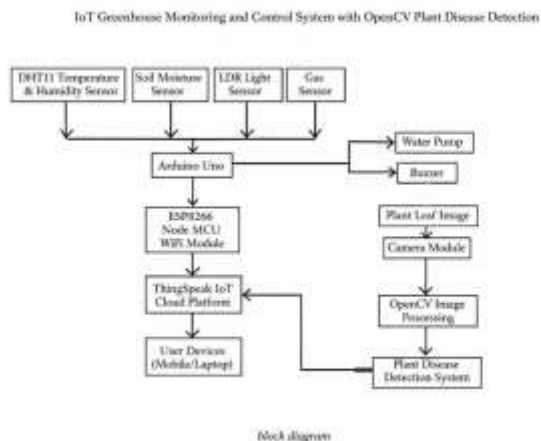


Fig. 1. Block diagram of the proposed method

B. Hardware Components

Arduino UNO: The Arduino UNO acts as the central microcontroller, processing data from sensors and controlling actuators. Its multiple I/O pins and reliability make it ideal for integrating several sensors, unlike older basic microcontrollers.

NodeMCU (ESP8266 Wi-Fi Module): NodeMCU enables real-time IoT communication, sending sensor data to the cloud for remote monitoring and control. It

simplifies the system compared to previous GSM-based designs..

DHT11 Sensor: DHT11 measures temperature and humidity digitally. This integrated sensor improves accuracy and reduces circuit complexity compared to separate analog sensors used in earlier studies.

Soil Moisture Sensor: It detects soil water content, enabling automated irrigation. This improves water efficiency and reduces human intervention compared to manual or timer-based systems.

LDR Sensor: The Light Dependent Resistor measures light intensity in the greenhouse. It helps control artificial lighting when natural light is insufficient, unlike older systems without automated light control

Water Pump / Motor: The water pump automates irrigation based on soil moisture readings. This ensures precise watering and better plant growth compared to manual pumps in previous works.

Artificial Light / LED: LEDs supplement natural light when needed, supporting consistent photosynthesis and uniform growth, a feature often missing in older systems.

Relay Module: Relays switch high-power devices like pumps, fans, and lights using low-power control signals. This ensures safe automation compared to manual switches in older systems.

Buzzer: The buzzer provides audible alerts when environment parameters exceed set thresholds, enhancing system responsiveness over visual-only indicators used previously.

Power Supply: A stable power supply supports all sensors, actuators, and controllers, ensuring continuous operation and avoiding the downtime issues seen in battery-dependent systems

Plant Leaf Image:

This block represents the actual plant leaf from which the system collects data. The condition of the leaf (color, spots, texture) is used to identify whether the plant is healthy or diseased.

Camera Module:

The camera module captures images of the plant leaf. These images act as the input for the disease detection system. Proper image capture ensures accurate analysis.

OpenCV Image Processing

The captured images are processed using OpenCV.

In this stage:

Noise is removed, Image is enhanced, Leaf features like color, edges, and patterns are extracted.

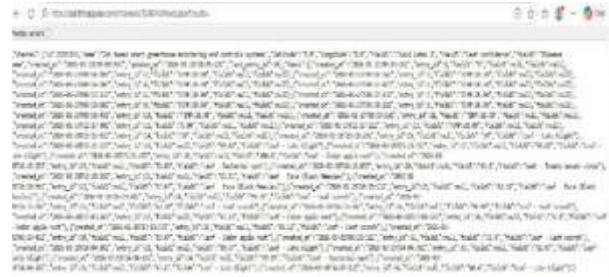
Plant Disease Detection System:

In this block, the processed image is analyzed to detect diseases. The system checks for: Spots or patches, Color changes (yellowing, browning)

Irregular patterns, Based on these features, the system determines whether the plant is healthy or infected.

ThingSpeak IoT Cloud Platform:

The detection results are sent to the cloud using the IoT platform. This allows: Storing plant health data, Monitoring remotely, Accessing results anytime.



OpenCV-based system successfully detects multiple plant diseases, confirming accurate image processing and classification through thingSpeak.

V II CONCLUSION

The **IoT Based Greenhouse Monitoring and Controlling System** successfully monitors important environmental parameters such as temperature, humidity, soil moisture, and light intensity using sensors like DHT11, soil moisture sensor, and LDR. The Arduino UNO processes the sensor data, while the NodeMCU (ESP8266) provides IoT connectivity and transmits the data to the cloud for remote monitoring.

The system helps farmers by providing real-time monitoring of environmental conditions, enabling better control over crop growth and reducing dependency on manual observation.

Using OpenCV, the project enables early detection of plant diseases, allowing farmers to take timely action and prevent major crop losses. Integration with ThingSpeak ensures that farmers can access data remotely, making it easier to monitor fields from anywhere. The use of Arduino makes the system cost-effective and affordable, which is highly beneficial for small and medium-scale farmers.

The system reduces manual effort and labor cost by automating monitoring and detection processes, improving overall farming efficiency. Overall, the project supports farmers in increasing crop productivity, improving decision-making, and promoting smart and sustainable agriculture practices.

V I RESULTS

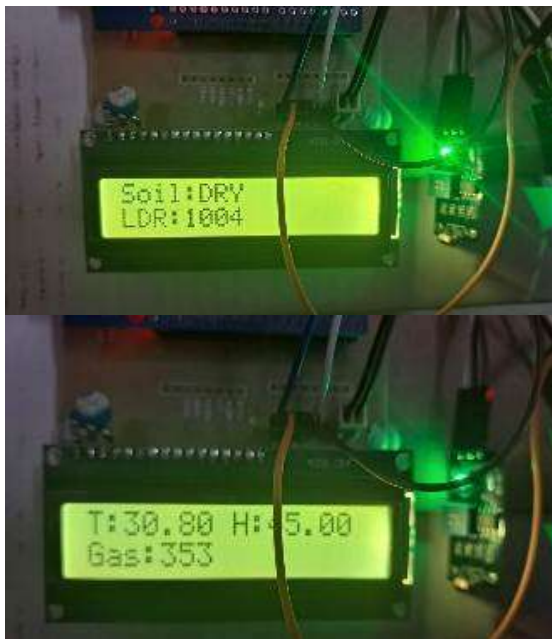


Fig. Results (soil moisture, light intensity, temperature and gas)

LCD displayed “Soil: DRY” and “LDR: 1004”, showing low soil moisture and high light intensity.

LCD showed Temperature (30.80°C), Humidity (45%), and Gas (353) readings.

Sensor data is continuously sent to the cloud via Arduino, showing proper IoT integration and stable temperature (28.5°C–28.9°C).

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