E-BOOK OF EXTENDED ABSTRACT

THE 14TH INTERNATIONAL INVENTION, INNOVATION & DESIGN COMPETITION 2025

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SMART GREENHOUSE MANAGEMENT SYSTEM USING ESP32-BASED IoT FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

The need for sustainable agriculture has driven for innovation in environmental monitoring and automation technologies. This project presents a smart greenhouse management system utilising the Internet of Things (IoT) to optimise crop growth conditions and reduce manual intervention through precise climate control and real-time monitoring. The system is controlled by a NodeMCU ESP32 microcontroller integrated with various sensors, including a DHT11 sensor, a light-dependent resistor (LDR) and a passive infrared (PIR) sensor. Based on real-time sensor data, actuators such as fans, exhaust fans, and lamps are automatically activated to maintain optimal growing conditions. Specifically, the DHT11 sensor regulates temperature and humidity via an exhaust fan, the LDR manages lighting based on ambient brightness and the PIR sensor triggers ventilation and lighting adjustments upon detecting motion. All components are programmed using the Arduino platform with remote monitoring and control through the flexible and user-friendly Blynk application. This innovative greenhouse monitoring system minimises manual effort and offers a cost-effective solution to support sustainable farming, aligning with the key global sustainability goals (SDGs) including food security, innovation, and climate action.

Keywords: smart greenhouse, greenhouse monitoring, IoT, NodeMCU, ESP32

1. INTRODUCTION

Agriculture plays a crucial role in ensuring food security and driving economic stability. However, modern agriculture faces increasing challenges such as climate variability, water scarcity, soil degradation and the increase of pests and diseases (Khalid et al., 2024). Traditional farming methods, on the other hand, which often depends on manual monitoring, may lack the precision and efficiency needed to overcome such challenges. As such, greenhouse farming has emerged as a promising solution that provides a controlled environment by mitigating external factors and stabilising growing conditions to enhance crop yield (Andrianto & Faizal, 2020). Thus, based on these concerns, the ability to monitor greenhouse environmental conditions is crucial, as it provides valuable insights for entrepreneurs to better understand how various factors influence plant growth and help them make data-driven decisions. Recent advancements have introduced the integration of the Internet of Things (IoT) into greenhouse management systems to support automation and remotely monitor environmental parameters such as temperature, humidity and light intensity (Bardi & Palazzi, 2022; Ghiasi et al., 2024; Zamani & Jumaat, 2023).

Motivated by this, the present project focuses on the development of a low-cost an IoT-driven smart greenhouse system utilising the ESP32 microcontroller, coupled with DHT11 (temperature and humidity), LDR (light intensity), and PIR (motion) sensors. The system employs the Blynk platform for remote monitoring and control accessible via mobile and desktop interfaces.

2. METHODOLOGY

2.1 System Development

Hardware and software are integrated to establish a smart greenhouse system where the environment is monitored and controlled. The hardware includes sensors, actuators and microcontroller NodeMCU ESP32 as shown in Table 1.

Table 1 Components of the smart greenhouse system

Category	Component	Function
Hardware	NodeMCU ESP32	Controller that integrates sensors, actuators and connects to the Blynk App.
	Expansion Board for ESP32	Extends connectivity for sensors and actuators.
	DHT11 Sensor	Measures temperature and humidity in the greenhouse.
	LDR Sensor	Detects ambient light levels to control lamp operation.
	PIR Sensor	Detects motion for automatic fan and lamp control.
	5V 4-Channel Relay Module	Interfaces between microcontrollers and actuators.
	Fan	Provide ventilation to regulate greenhouse temperature.
	Exhaust fan	Expels hot and humid air to maintain optimal climate conditions.
	Lamp	Provides artificial lighting when natural light is insufficient.
Software	Arduino IDE	Platform used for coding and uploading programs to the ESP32.
	Blynk App	IoT apps are utilized for remote control and real-time monitoring.

2.2 System Implementation

The block diagram of the smart greenhouse system, as shown in Figure 1 utilises a NodeMCU ESP32 to automate agricultural functions by responding to real-time data from sensors. The DHT11 sensor monitors temperature and humidity, activating the exhaust fan when conditions get too hot or humid. The PIR sensor detects motion to turn on the fan and lamp for ventilation and visibility, while an LDR sensor controls the lamp based on light levels, switching it on at night. All devices are managed through a relay module and the system can be monitored or controlled remotely using the Blynk app.

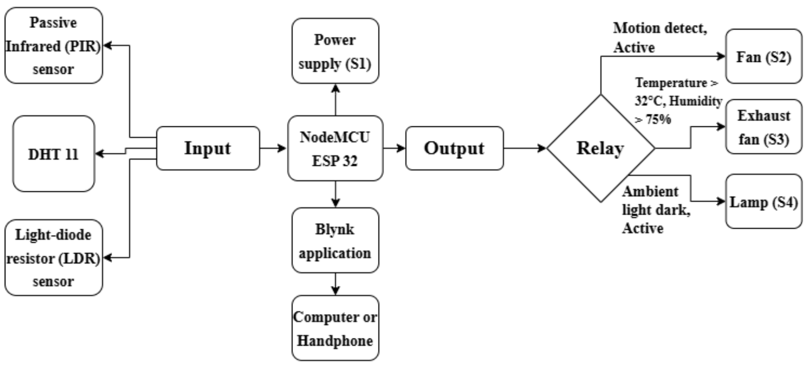

Figure 1 Block diagram of the system

3. FINDINGS

The smart greenhouse system is integrated with four main switches, each controlling specific relays and devices. Switch S1 supplies 12 V power to activate the NodeMCU ESP32 and the expansion board, activating the entire system that enables communication and allows communication between the sensors and actuators. Switch S2 is connected to Relay R1 to control the fan, which is triggered when the PIR sensor detects motion. Switch S3 operates the exhaust fan via Relay R2, which responds to input from the DHT11 sensor—activating the fan when the temperature exceeds 32°C or humidity rises above 75% to maintain a stable internal environment. Finally, Switch S4, connected to Relay R3, controls the lamp, which is turned on when the LDR sensor detects low ambient light levels. Figure 2 illustrates the prototype of the smart greenhouse system, showcasing the physical integration of the sensors, actuators, and microcontroller hardware.

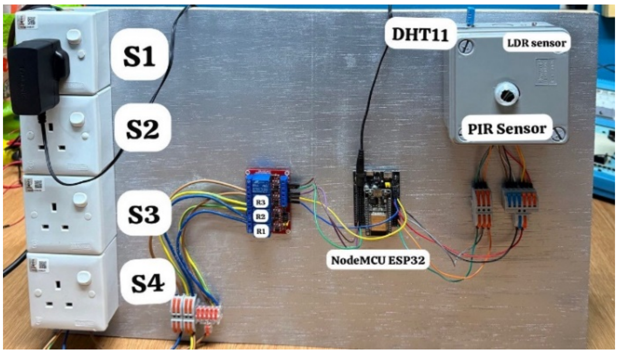

Figure 2 Prototype of the system

Figure 3 shows the Blynk interface of the smart greenhouse system. The Blynk interface provides a user-friendly platform that enables remote monitoring and control of the smart greenhouse system through virtual pins assigned to each component. It offers real-time data visualisation and manual override features, ensuring that users can manage the environment efficiently from anywhere using a mobile device. By connecting the NodeMCU ESP32 to a mobile phone's hotspot, the system maintains real-time communication with the Blynk app, enabling remote monitoring and control regardless of location. Temperature and humidity readings from the DHT11 sensor are displayed using gauges connected to V5 and V4 while the exhaust fan can be manually controlled via V1. Besides, the lamp is managed through Relay R3 and controlled using V3 with additional switches for day and night modes assigned to V6 and V7. The fan triggered by motion detection is controlled through V2. PIR sensor's status is shown on a label linked to V0. This interface makes it easy to oversee and operate the entire system from a mobile device.

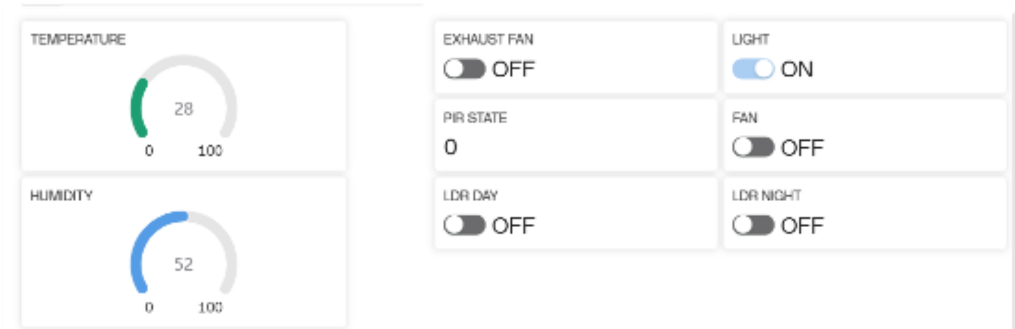

Figure 3 Blynk interface of the system

4. CONCLUSION

This study demonstrates the feasibility of an IoT-based smart greenhouse management system that enables real-time monitoring and control of key environmental parameters. By integrating the ESP32 microcontroller with DHT11, LDR, and PIR sensors, and utilising the Blynk platform for remote access, the system supports efficient and sustainable agricultural practices. The proposed solution offers a cost-effective, scalable approach that bridges the gap between traditional methods and modern smart farming technologies.

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