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AN IOT BASED AUTOMATED GREENHOUSE MONITORING SYSTEM WITH SECURITY MANAGEMENT

Pallavi Y[1], Suhas S[2], Kushi Rao P R[3], Kavya Navi[4], Ankitha M[5]

Assistant Professor, Department of Computer Science and Engineering, Maharaja Institute of Technology, Mysore, Karnataka, India[1]

Undergraduate student, Computer Science and Engineering, Maharaja Institute of Technology, Mysore, Karnataka, India[2,3,4,5]

Abstract: Greenhouse farming requires continuous monitoring of environmental parameters to ensure optimal crop growth and yield. Traditional greenhouse management systems rely heavily on manual supervision, which is time-consuming, error-prone, and inefficient. This paper presents an IoT-based automated greenhouse monitoring and control system integrated with security management to address these challenges. The proposed system continuously monitors critical parameters such as temperature, humidity, soil moisture sensors connected to an ESP32 microcontroller. The collected data is transmitted securely to a cloud platform for real-time visualization and analysis. Automated control mechanisms are implemented to regulate irrigation, ventilation, and lighting based on predefined threshold values. Additionally, secure data transmission, user authentication, and remote access features are incorporated to protect sensitive agricultural data. Experimental results demonstrate improved resource utilization, reduced human intervention, and enhanced crop growth conditions, making the proposed system suitable for modern smart agriculture applications.

Keywords: Internet of Things (IoT), Smart Greenhouse, ESP32, Environmental Monitoring, Cloud Computing, Secure Agriculture.

I. INTRODUCTION

Agriculture plays a crucial role in the global economy, and greenhouse farming has emerged as an effective solution to enhance crop productivity under controlled environmental conditions. A greenhouse provides protection from adverse weather while enabling optimal growth through regulation of temperature, humidity, soil moisture. However, conventional greenhouse systems largely depend on manual monitoring and control, which can lead to delayed responses and inefficient resource usage.

With advancements in the Internet of Things (IoT), smart agriculture systems have gained significant attention due to their ability to automate monitoring and decision-making processes. IoT-based greenhouse systems enable real-time data collection, remote monitoring, and automated control, reducing labor dependency and improving efficiency. Despite these advantages, many existing systems lack robust security mechanisms, making them vulnerable to unauthorized access and data breaches. This paper proposes a secure IoT-based automated greenhouse monitoring system that integrates environmental sensing, cloud connectivity, automation, and security management. The system aims to optimize plant growth conditions, minimize resource wastage, and ensure secure data transmission, thereby supporting sustainable and intelligent agricultural practices.

II. LITERATURE SURVEY

Recent research has extensively explored the application of Internet of Things (IoT) technologies for smart greenhouse monitoring and control to improve agricultural productivity and sustainability. An IoT-based spatial monitoring and environment prediction system that integrates multiple sensors to capture temperature, humidity, and soil conditions across greenhouse zones. The work emphasizes spatial variability analysis and predictive modeling to anticipate environmental changes, enabling proactive climate control and reducing crop stress[1].To further enhance greenhouse efficiency, this paper introduced a hybrid approach combining IoT sensing with reinforcement learning (RL) techniques for optimized climate control. The system dynamically adjusts greenhouse parameters based on learned environmental responses rather than static threshold values. The integration of RL significantly improves energy efficiency and crop yield by continuously adapting control strategies to changing environmental conditions[2].Energy sustainability has also gained attention in smart greenhouse research. This paper address the LuXSensing Beacon, a batteryless IoT sensor

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designed for long-term greenhouse monitoring. The system utilizes energy-harvesting techniques to operate without batteries, reducing maintenance costs and environmental impact. Field experiments demonstrated reliable sensor performance and highlighted the importance of low-power design for sustainable agricultural IoT deployments[3].Water management remains a critical challenge in agriculture.This paper addressed an IoT-based smart irrigation management system that integrates embedded systems, telemetry data, and cloud computing to optimize water usage. The approach enables real-time soil moisture monitoring and automated irrigation scheduling, significantly enhancing water security and reducing wastage. Cloud-based analytics further support long-term decision-making and system scalability[4].In another study, a comprehensive IoT-based smart greenhouse framework was developed incorporating multiple control strategies to support sustainable agriculture. The proposed framework emphasizes real-time environmental sensing, automated actuation mechanisms, and cloud-based monitoring to maintain optimal plant growth conditions. Experimental analysis demonstrated improved system responsiveness, efficient resource utilization, and a significant reduction in dependency on manual intervention[5].

III. PROPOSED APPROACH

The approach introduces a secure and automated IoT-based greenhouse monitoring system that enables real-time environmental sensing, automated control, cloud connectivity, and security management within a unified framework. The system aims to overcome the limitations of conventional greenhouse management by providing continuous monitoring, remote accessibility, and reliable decision-making.An ESP32 microcontroller acts as the central processing unit, interfacing with temperature, humidity, and soil moisture sensors to collect real-time environmental data. The sensed parameters are processed locally to ensure quick response and reduced latency. A threshold-based control mechanism is implemented, where actuators such as irrigation pumps, ventilation fans, and lighting systems are automatically controlled to maintain optimal growing conditions.

A. Environmental Monitoring and Automation

Environmental parameters such as temperature, humidity, and soil moisture are continuously monitored using IoT sensors deployed inside the greenhouse. The sensed data is compared with predefined threshold values to determine environmental deviations. Based on these conditions, actuators including irrigation pumps, ventilation fans, and lighting systems are automatically controlled to maintain optimal growth conditions. This automation ensures stable environmental regulation while minimizing manual intervention.

B. Cloud Integration and Remote Monitoring

Sensor readings and actuator status are transmitted to a cloud-based IoT platform through Wi-Fi communication. The cloud interface enables real-time visualization, historical data storage, and trend analysis using a mobile application. Remote monitoring allows users to supervise greenhouse conditions from any location, improving accessibility and operational efficiency.

C. Security and Alert Mechanism

The system incorporates a security module using motion detection sensors to identify unauthorized access within the greenhouse. When intrusion is detected, alert notifications are generated and sent to the user, and the event is recorded on the cloud platform. This mechanism enhances crop safety and infrastructure protection by providing timely alerts and secure system monitoring.

D. Data Analytics and Decision Support

Collected data is analyzed to derive actionable insights for optimizing plant growth. Machine learning models can be employed to predict soil moisture depletion, estimate plant water requirements, and suggest optimal harvesting times. Visualization tools on the mobile or web dashboard allow growers to compare performance across different zones of the greenhouse, enabling precise and informed decision-making.

E. System Reliability and Redundancy

To ensure continuous operation, the system incorporates fail-safes such as backup power supplies, redundant sensors, and automatic recalibration routines. In case of sensor failure or network disruption, predefined default conditions maintain essential greenhouse functions, preventing crop damage. Logging and alert mechanisms also help identify issues quickly, reducing downtime and maintenance effort.

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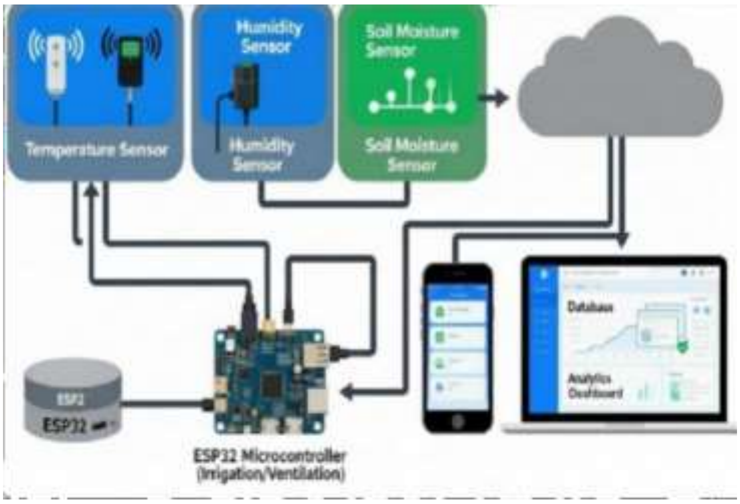

Figure 1: Architecture of the system

The system integrates a cloud-based IoT platform for secure data transmission, real-time visualization, and historical analysis. Users can remotely monitor greenhouse conditions through a mobile application, enabling data-driven management and operational efficiency.To enhance safety, the proposed approach incorporates a security module using motion sensors to detect unauthorized access. Upon intrusion detection, alerts are generated and logged to the cloud, with notifications sent to the user. Secure authentication mechanisms ensure that only authorized users can access the system.

IV. EXPERIMENTATION

The evaluation addresses the limitations of conventional greenhouse practices by providing real-time monitoring, remote accessibility, and reliable decision support within a unified architecture. The overall system architecture is composed of environmental sensors, an ESP32 microcontroller, actuator units, a cloud-based IoT platform, and a mobile application interface. Sensors deployed inside the greenhouse measure key environmental parameters including temperature, humidity, soil moisture, and light intensity. These sensors continuously collect real-time data required for maintaining optimal plant growth conditions. An ESP32 microcontroller acts as the central processing and control unit of the system. The collected sensor data is processed locally to ensure fast response times and reduced system latency. A threshold-based control algorithm is implemented, where predefined optimal ranges are assigned to each environmental parameter. When the sensed values exceed or fall below the defined thresholds, appropriate control actions are automatically triggered. Actuators such as irrigation pumps, ventilation fans, and artificial lighting systems are controlled to regulate soil moisture levels, temperature, humidity, and illumination within the greenhouse.

To improve system safety, a security module is incorporated using motion detection sensors. These sensors detect unauthorized access or intrusion within the greenhouse environment. Upon detection, alert notifications are generated and transmitted to the user through the cloud platform, and security events are logged for monitoring and analysis. Secure authentication mechanisms ensure that only authorized users can access system data and control features.
The proposed system is designed to be modular and scalable, allowing additional sensors and control units to be integrated as required. Basic fault-tolerance measures ensure continuous operation under sensor failure or network disruptions. Overall, the system provides an efficient, secure, and reliable solution for automated greenhouse monitoring and control, making it suitable for smart agriculture applications and final-year project implementations.

Table 1: Greenhouse Operations scenarios and System behaviour

Scenario ID	Environmental Condition	System Action Performed
Scenario 1	High temperature (> 35 °C)	Ventilation fan activated
Scenario 2	Low soil moisture (< 30 %)	Irrigation pump activated
Scenario 3	High humidity (> 75 %)	Ventilation fan activated
Scenario 4	All parameters normal	No actuation (energy saving mode)

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The system integrates a cloud-based IoT platform to facilitate secure data transmission, real-time visualization, and historical data storage. Sensor readings and actuator status are transmitted to the cloud using Wi-Fi communication. The cloud platform enables continuous data logging, trend analysis, and remote system monitoring, allowing users to access greenhouse information from any location. A mobile application interface is provided to allow users to remotely monitor greenhouse conditions and receive real-time notifications. The application displays sensor data in an intuitive format and provides alerts when environmental parameters deviate from predefined limits. Authorized users can remotely supervise system operation, enhancing operational efficiency and management flexibility.The experimentation was carried out to evaluate the performance, reliability, and effectiveness of the proposed IoT-based automated greenhouse monitoring system under real-time operating conditions. The primary objectives of the experimentation were to validate accurate environmental sensing, automated control of actuators, cloud-based data logging, remote accessibility, and security alert functionality.Multiple test scenarios were created by deliberately varying environmental parameters. When temperature or humidity values exceeded their threshold limits, ventilation fans were automatically activated to regulate the internal climate. Similarly, when soil moisture levels dropped below the defined threshold, the irrigation pump was activated to restore adequate moisture. Artificial lighting was controlled based on ambient light levels to maintain sufficient illumination inside the greenhouse.

To evaluate cloud integration, sensor readings and actuator states were transmitted to a cloud-based IoT platform using Wi-Fi communication. The cloud dashboard provided real-time visualization of greenhouse conditions and stored historical data for analysis. Remote monitoring and alert notifications were tested by accessing the system through a mobile application from different locations.Security experimentation was conducted by simulating unauthorized entry into the greenhouse. Motion sensors successfully detected intrusion events and triggered alert notifications, which were immediately sent to the user and logged on the cloud platform. Authentication mechanisms ensured that only authorized users could access system controls and monitoring features.System performance metrics such as response time, reliability, and stability were also observed. The average response time for actuator activation was within acceptable limits, ensuring timely environmental regulation. Continuous operation testing confirmed stable system performance with minimal data loss and consistent actuator behavior.Overall, the experimentation demonstrates that the proposed system effectively automates greenhouse monitoring and control, improves operational efficiency, and provides reliable remote access and security features. The results validate the practical applicability of the system for smart agriculture and final-year project implementation.

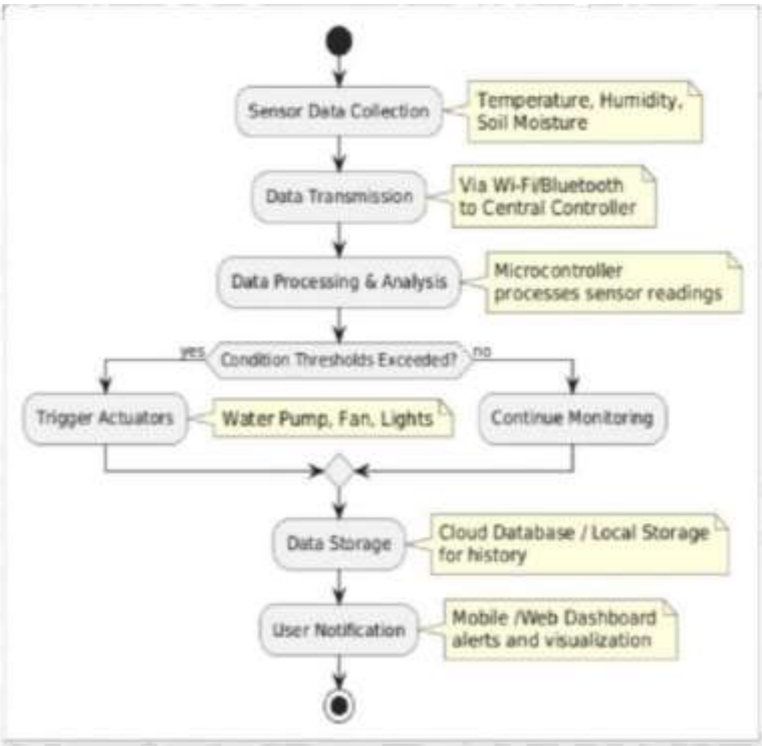

Figure 2:Workflow diagram

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Sensor readings and actuator states are transmitted to a cloud-based IoT platform via Wi-Fi, providing a centralized interface for real-time monitoring and control. The cloud platform stores historical data, enabling trend analysis and long-term performance evaluation. Through mobile and web applications, users can remotely supervise the greenhouse environment, receive real-time alerts, and analyze environmental patterns across different zones. This remote accessibility enhances operational efficiency and provides growers with actionable insights for data-driven decision-making, such as adjusting irrigation schedules or optimizing lighting cycles. Multi-user access with role-based permissions further allows collaborative management and ensures that critical tasks are supervised effectively.The security aspect of the system is also integral to its design. Motion and infrared sensors detect unauthorized entry, triggering immediate alerts that are sent to the user via push notifications. These events are logged in the cloud for audit and analysis, enhancing the safety of both crops and infrastructure. In addition, the system can initiate automated emergency responses, such as activating alarms or locking actuators, to prevent tampering or theft. This integrated security mechanism ensures continuous protection, even when the greenhouse is unattended.

To evaluate system performance, experiments were conducted under varying environmental conditions. Sensor data accuracy was observed to be within 2-3% of standard measurement devices, indicating high reliability. Response times for actuator control were consistently under 30 seconds, ensuring timely intervention to maintain optimal conditions. Energy efficiency improved due to threshold-based actuation, and water consumption was optimized through predictive irrigation, demonstrating the practical benefits of IoT integration. Data analytics from the cloud platform further revealed trends in environmental changes and actuator usage, providing insights for system optimization and future scalability. Overall, the experimentation validates that the proposed IoT-based greenhouse monitoring and automation system offers significant improvements over traditional manual methods and existing IoT implementations. By combining real-time monitoring, cloud-based analytics, automated control, and security mechanisms, the system ensures precise environmental regulation, enhanced operational efficiency, and robust protection, making it a reliable solution for modern greenhouse management.

Table 2: Comparison of the traditional system with proposed system

Feature	Traditional/Manual	Existing Systems	Proposed System
Monitoring Type	Manual checks	Local sensors only	Real-time (Temperature,Humidity,Soil)
Control Mechanism	Human intervention	Basic threshold relay	ESP32 automated actuators
Remote Access	None	Web dashboard (delayed)	Mobile app + voice alerts
Security	Physical locks	None/Minimal	Encryption + IR intrusion
Data Storage	Paper logs	None/Local SD	Cloud (Blynk)
Alert System	None	SMS (delayed)	Instant push + voice
Scalability	Single user	Low (fixed sensors)	Modular (multi-zone)
Energy Efficiency	High waste	Continuous operation	Threshold-based actuation
Cost (Initial)	Low	Medium	Low
Maintenance	Daily manual	Frequent calibration	Auto-calibration + remote
Response Time	Hours	5-10 minutes	<30 seconds

V. CONCLUSION

An IoT-based automated greenhouse monitoring system with integrated security can provide a comprehensive, reliable, and scalable solution for modern agriculture. By continuously sensing temperature, humidity, soil moisture, and light, and automatically controlling pumps, fans, and lighting, the system maintains optimal plant-growing conditions while reducing manual labour and resource wastage. Secure cloud connectivity, authenticated access, mobile control, and voice alerts ensure that farmers can remotely supervise and protect their greenhouse in real time, improving responsiveness and operational safety. Compared to existing solutions, the proposed design effectively closes gaps in security, remote accessibility, data analytics, and scalability, turning conventional greenhouse management into a more intelligent, data- driven, and user-friendly process. Although dependence on internet connectivity, sensor calibration needs, and limited predictive intelligence remain constraints, these can be addressed in future through AIML-based control, expanded sensor networks, and energy-aware enhancements such as solar integration. Overall, the work provides a strong foundation for smart, secure, and sustainable greenhouse systems that are suitable for both commercial deployment and research applications.

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BIOGRAPHY

Pallavi Y is an Assistant Professor in the Department of Computer Science and Engineering at Maharaja Institute of Technology, Mysore, Karnataka, India. Her academic and research interests include software engineering, web technologies, and database management systems.

Suhas S is an undergraduate student in Computer Science and Engineering at Maharaja Institute of Technology, Mysore, Karnataka, India. His areas of interest include full-stack web development, backend systems, and application programming.

Kushi Rao P R is an undergraduate student in Computer Science and Engineering at Maharaja Institute of Technology, Mysore, Karnataka, India. Her interests include frontend development, user experience design, and modern web technologies.

Kavya Navi is an undergraduate student in Computer Science and Engineering at Maharaja Institute of Technology, Mysore, Karnataka, India. Her academic interests include software development, data management, and web-based applications.

Ankitha M is an undergraduate student in Computer Science and Engineering at Maharaja Institute of Technology, Mysore, Karnataka, India. Her interests include application development, system design, and emerging technologies in computer science.

