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Internet of Things (IoT) Based Greenhouse Monitoring and Controlling System Using ESP-32

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Abstract: Greenhouse agriculture is pivotal for enhancing crop yield and quality, but existing systems often grapple with precision and control limitations. This paper introduces a revolutionary ESP32-based greenhouse monitoring and control system, featuring remote capabilities. Utilizing advanced sensors and actuators, the system ensures real-time data acquisition and automated environment modulation. It aims to overcome conventional drawbacks with seamless connectivity and a user-friendly interface. The ESP32 microcontroller serves as the system's core, enabling robust processing and Wi-Fi connectivity. Strategic sensor placement allows continuous monitoring, while actuators automate adjustments for optimal growth conditions. Integration of IoT technology enables remote monitoring and control, offering real-time access globally. This innovation promises enhanced efficiency, resource optimization, and improved crop yield through automated, IoT-based remote monitoring, marking a significant stride in greenhouse agriculture, and addressing the complexities of contemporary farming practices.

Keywords: Greenhouse Automation, ESP32 Microcontroller, IoT-enabled Agriculture, Remote Environmental Monitoring, Precision Crop Control.

I. INTRODUCTION

Greenhouse stands at the forefront of modern crop cultivation, offering a meticulously controlled environment that catalyzes superior yield and quality. The regulated conditions within greenhouses, meticulously adjusting factors like temperature, humidity, moisture levels, and light, have proven pivotal in optimizing plant growth. However, contemporary greenhouse monitoring systems grapple with challenges, particularly in achieving precision and control, accentuated in remote scenarios where real-time monitoring becomes imperative. In response to these challenges, this research introduces a groundbreaking solution—an IOT-based greenhouse monitoring and control system using ESP 32. This innovative approach not only prioritizes real-time monitoring capabilities but also seamlessly integrates automation into the control processes. At the core of this system is the versatile ESP32 microcontroller, chosen for its robust Wi-capabilities. Integral to our system is the fusion of advanced sensors and actuators, facilitating real-time data acquisition from the greenhouse environment. Continuous monitoring of critical metrics influencing plant growth—temperature, humidity, soil moisture, and light intensity—is made possible. Advanced actuators allow for autonomous adjustments to these environmental factors, ensuring an optimal growth environment for crops.

A defining feature of our system is its seamless connectivity, enabled by the ESP32's Wi-Fi capabilities. This facilitates remote monitoring from any location with internet access, effectively overcoming a significant limitation in many existing systems. Notably, while remote monitoring is enabled, the control processes are designed to function autonomously, minimizing the need for external interference.

Augmenting user accessibility and ease of operation is the user-friendly interface of our system. Through an intuitive dashboard, farmers and greenhouse operators gain insights into real-time data and the system's status. This interface empowers users to make informed decisions regarding the cultivation environment, fostering a proactive approach to greenhouse management.

The proposed system aspires to revolutionize greenhouse agriculture by alleviating the drawbacks associated with conventional approaches. Enhanced efficiency, resource optimization, and improved crop yield emerge as the anticipated outcomes of this IoT-based solution. The automation of control processes ensures a hands-free operation, significantly reducing the dependency on constant human intervention.

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As a result, this research identifies the limitations of existing greenhouse monitoring systems and pioneers a viable and innovative solution. Leveraging the capabilities of the ESP32, advanced sensors, and automated control processes, our system contributes to the evolution of smart and sustainable greenhouse management. The implications of this research extend beyond greenhouse agriculture, embracing the broader context of precision agriculture, where technology plays a pivotal role in ensuring food security and sustainability.

II. RELATED WORKS

The Internet of Things (IoT) is rapidly transforming greenhouse management, offering a powerful toolbox for optimizing plant growth and agricultural practices. This technology allows seamless device connectivity and data transfer over the internet, enabling remote monitoring and control capabilities. Researchers are leveraging the power of IoT to develop innovative solutions that address the challenges faced by traditional greenhouse management. Several studies have explored the potential of IoT in this domain. Blessy Mathew et al. [1] present a groundbreaking solution that tackles manual monitoring. Their system utilizes advanced sensors and a Raspberry Pi3 to autonomously regulate key environmental factors. Data is securely stored in the cloud, accessible through a user-friendly interface, demonstrating the seamless integration of IoT for efficient and automated greenhouse operations. This approach significantly contributes to enhanced plant growth and maximized crop yield.

Sampaio and Motoyama [2] delve into Wireless Sensor Networks (WSNs) for agriculture. Their paper proposes a unique hierarchical structure for WSNs, distinct from traditional approaches, to improve scalability and efficiency in large-scale greenhouses. Promising results from lab settings suggest this model has the potential to address challenges in scaling WSNs for practical applications.

Another study explores precision agriculture using greenhouses, IoT, and cloud computing [3] (authors' names missing). This approach integrates sensor networks to ensure optimal environmental conditions for diverse crops. The system empowers remote control through IoT and transmits data to users via the cloud, providing them with real-time insights for informed decision-making.

Building upon this foundation, another study [4] proposes an IoT-driven Hydroponics system that leverages the UBIDOTS cloud platform. This fully automated system utilizes sensors and actuators to optimize photosynthesis with artificial lighting, while simultaneously monitoring and adjusting various greenhouse conditions. Users gain valuable visual representations of their greenhouse environment through real-time data access on the UBIDOTS cloud platform.
Kodali et al. [5] present a smart greenhouse model that integrates cutting-edge technology for enhanced agricultural practices. The system incorporates automatic irrigation, fertigation, and climate control, promoting organic farming, reducing water usage, and ultimately generating additional income for individual users.

Subahi and Bouazza [6] introduce a scalable IoT-based system specifically designed for smart greenhouse farming in Saudi Arabia. Their innovation incorporates a controlled awning to manage sun exposure, and captured data is structured within a dynamic Neo4j graph database, enabling efficient information management for large-scale operations.

Several studies emphasize the importance of sensor deployment and real-time data collection for monitoring critical environmental parameters affecting plant growth. Research by [7] details a greenhouse monitoring and control system that merges IoT and WSN technologies. The integration of these technologies facilitates automated control mechanisms, allowing for optimization of greenhouse conditions to improve crop yield and resource efficiency. The study's findings demonstrate significant advancements in agricultural practices through the effectiveness and scalability of the proposed system.

This focus on sensor deployment and real-time data collection for optimizing environmental conditions is echoed in studies by [8, 9, and 10]. These papers all explore IoT based greenhouse environment monitoring and control systems, highlighting the role of sensor data in creating ideal conditions for enhanced crop growth and resource utilization. The results across these studies consistently demonstrate the efficacy of such systems in improving overall greenhouse management practices.

Another approach is explored in research by [11] which details the design and implementation of a greenhouse monitoring and control system utilizing Wireless Sensor Networks (WSNs). Presented at a major conference (2018 IEEE 11th Cairo International Biomedical Engineering Conference), the system focuses on real-time data collection and automated control strategies for optimizing greenhouse conditions. The results showcase its effectiveness in enhancing crop growth and resource efficiency.

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Similarly, a system presented at the 2020 IEEE 10th Symposium on Computer Applications & Industrial Electronics is described in [12]. This system is based on Internet of Things (IoT) technology and focuses on the system's architecture, particularly the utilization of IoT enabled sensors for real-time data collection and automated control mechanisms. The findings indicate the system's efficacy in optimizing greenhouse conditions for improved crop yield and resource management.

The final study by [13] highlights the implementation of IoT for real-time data acquisition and machine learning algorithms for predictive analytics to optimize greenhouse conditions. Results underscore the system's efficacy in enhancing crop yield and resource efficiency through intelligent greenhouse management. This literature survey demonstrates the immense potential of IoT for revolutionizing greenhouse management. By leveraging real-time data collection, automated control mechanisms, and innovative system designs, researchers are paving the way for a future of efficient, sustainable, and high yielding agriculture.

III. PROPOSED METHODOLOGY

The primary goal is to establish a fully automated greenhouse management system utilizing the ESP32 microcontroller

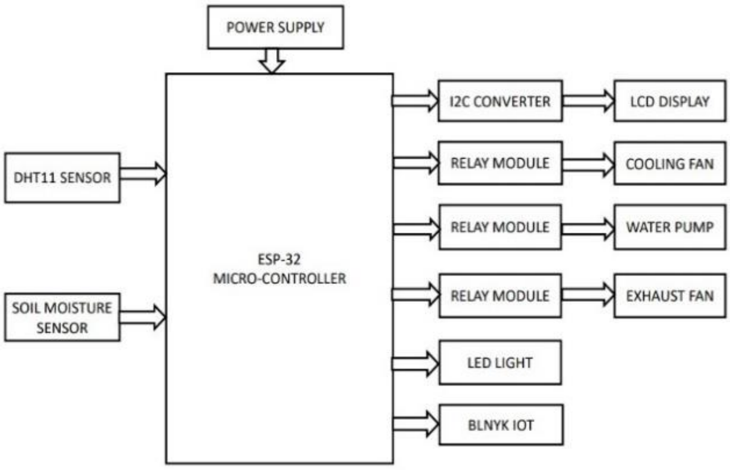

Figure 1: Block diagram

Key sensors, including a soil moisture sensor and a DHT11 sensor, are seamlessly integrated into the system for real-time assessment of soil moisture, temperature, and humidity within the greenhouse. For monitoring purposes, an on-site 16x2 LCD and the Blynk mobile application enable immediate access to sensor readings. The ESP32's Wi-Fi capabilities allow remote monitoring and control, emphasizing that the system operates autonomously without requiring human intervention.

Automation plays a crucial role in optimizing the greenhouse environment. The ESP32 activates a water pump to maintain optimal soil moisture levels, and 5Vmini-DC fans operate based on both daytime and nighttime conditions, ensuring effective climate control.

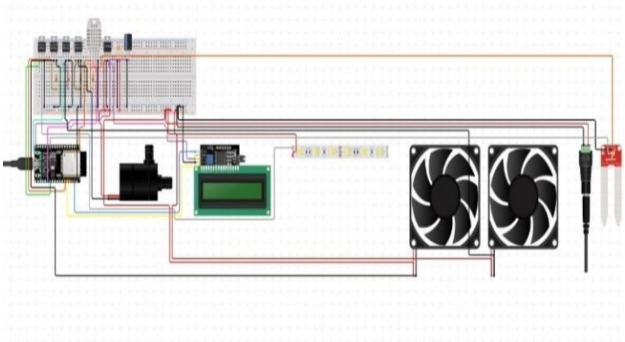

Figure2: Circuit diagram.

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Temperature and humidity levels are carefully maintained throughout the day, with the water pump activating when soil moisture falls below 30%, preventing under-watering and ensuring an ideal growth environment. Nighttime conditions slightly adjust to maintain a balanced and healthy environment for plant growth.

An integrated LED light controlled by the ESP32regulates light exposure, promoting optimal plant growth. The decision-making algorithm within the ESP32's code dynamically activates or deactivates the water pump, fans, and LED light based on predefined thresholds, ensuring responsiveness to varying greenhouse conditions.

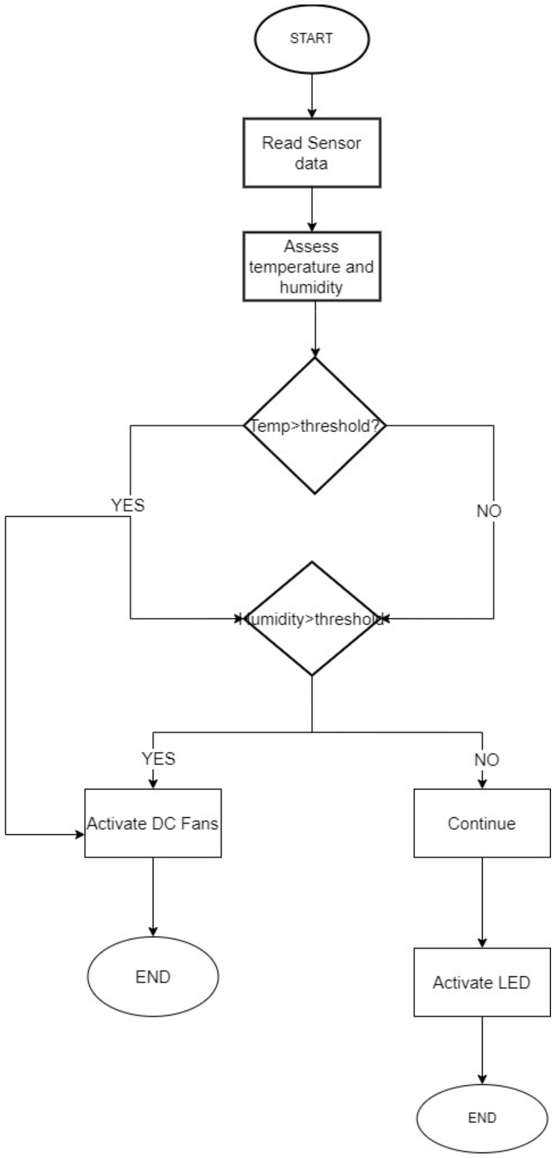

Figure 3: Flowchart 1

The above flowchart which is Fig3: flowchart 1 is the logic explaining monitoring and controlling the temperature and Humidity levels in the greenhouse.

The flowchart which is in the fig4: flow chart 2 is the logic explaining about reading the soil moisture sensor data and controlling it with the water pump ON and OFF.

To enhance user experience, a user-friendly interface is designed on the Blynk app, emphasizing simplicity for remote monitoring. Rigorous testing is conducted to validate sensor readings, with calibration optimizing performance across diverse greenhouse environments.

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Documentation underscores the system's architecture, codebase, and configurations for clarity, with scalability considerations for potential expansions.

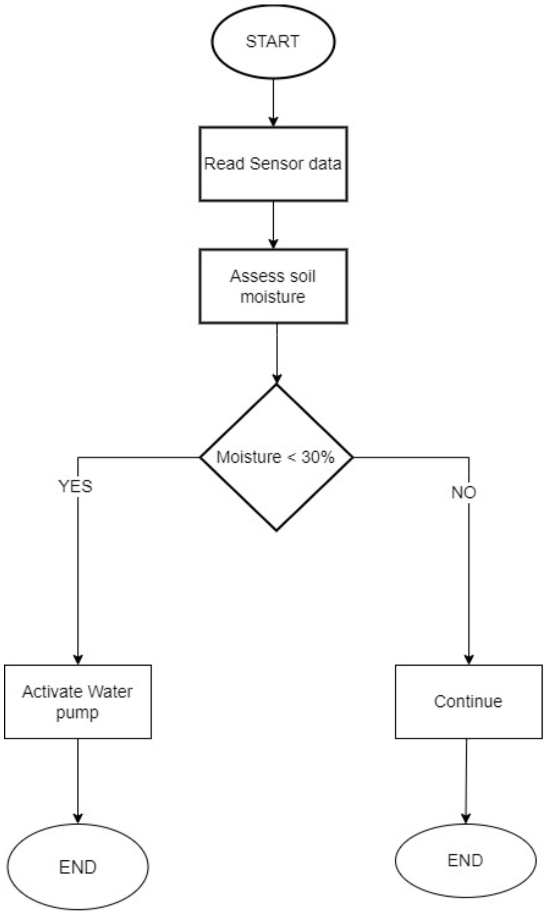

Figure 4: Flowchart 2

IV. IMPLEMENTATION & RESULTS

In the implementation, the Utilized space is 15cm in width and 30cm in length. This compact area served as the experimental environment for testing and evaluating the efficacy of the proposed ESP32-based greenhouse monitoring and control system. The limited dimensions of the space necessitated careful consideration and optimization of sensor

Figure 5: working model of monitor and control

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placement, actuator functionality, and overall system design to ensure optimal performance within the constrained area. By leveraging advanced technologies and strategic planning, the system effectively demonstrated its capabilities in maintaining ideal growth conditions for plants within this confined greenhouse space.

The inclusion of an image showcasing Blynk results is pivotal in the paper, offering a visual representation of the ESP32-based greenhouse monitoring system's real-time capabilities. Through the Blynk mobile app, users can access crucial sensor data like soil moisture temperature, and humidity instantly. This image highlights the system's seamless integration with Blynk, showcasing its user-friendly design and remote accessibility. It emphasizes the system's effectiveness in providing remote monitoring and control.

Figure 6: serial monitor output.

The image provides a detailed insight into the sensor data captured by the DHT11 and soil moisture sensors, both crucial components in our experimental setup. Notably, the soil moisture sensor is connected to an analog pin, enabling continuous monitoring of soil moisture levels. Concurrently, the DHT11 sensor data refreshes every 2 seconds, offering a near-real-time update on temperature and humidity conditions. This snapshot, extracted from the Arduino IDE's Serial Monitor, encapsulates the dynamic nature of our data collection process, highlighting the timely acquisition and monitoring capabilities inherent in our experimental framework.

Figure 7: Blynk output

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V. CONCLUSION

The new greenhouse monitoring and control system powered by ESP32 is a game-changer in farming technology. It's like going from an old flip phone to a sleek smartphone overnight. This system is packed with fancy sensors, actuators, and IoT tech that automatically keep a constant eye on the greenhouse and automatically tweak conditions. It's all about giving plants the perfect environment to thrive without the need for constant human intervention. And the best part? It's super user-friendly and can easily connect to your phone or computer without any hassle. This means less time stressing over greenhouse management and more time focusing on important tasks. Plus, it's eco-friendly and can even boost crop yields. As we continue to refine and develop this technology, it has the potential to completely revolutionize greenhouse farming, making it more sustainable and secure for future generations.

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