Greenhouse Monitoring and Control System using IOT

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Abstract : ***This project describes the development of an IoT-based greenhouse monitoring and control system using the Raspberry Pi Pico microcontroller integrated with various sensors (DHT11 for temperature and humidity, LDR for light, and a soil moisture sensor) and actuators (fan, pump, humidifier, and light). The Raspberry Pi Pico collects real-time data from the environment, displays readings on a local LCD, and uploads sensor values to the ThingSpeak cloud via an ESP8266 module for remote visualization and monitoring. System logic automatically controls actuators when sensed parameters cross predefined thresholds, assisting optimal plant growth and resource efficiency. This solution offers a cost-effective, flexible, and scalable approach for modern agriculture applications, especially supporting remote environmental management for greenhouses.***

Index Terms: Internet of Things, webserver, greenhouse, agriculture, control systems, sensors

I. INTRODUCTION

Greenhouses are crucial for modern agriculture, enabling year-round crop production and improved yields. However, maintaining optimal conditions can be challenging, especially in large-scale operations. Manual monitoring and control can lead to inefficiencies, increased labor costs, and reduced crop quality. Our IoT-based Greenhouse Monitoring and Control System addresses these challenges, providing a scalable, automated solution for farmers and greenhouse managers.

The system integrates sensors, actuators, and IoT technology to create a seamless monitoring and control experience. Real-time data is collected and analyzed, enabling informed decisions and automated adjustments to optimize greenhouse conditions. This results in improved crop yields, reduced resource consumption, and enhanced overall efficiency.

Greenhouses require stable and optimized environmental conditions to maximize plant growth and productivity. Weather fluctuations in external environments can challenge maintaining constant conditions. Automation with IoT technology addresses these challenges by enabling precise monitoring and remote or automatic control of temperature, humidity, light, and soil moisture. In this project, a Raspberry Pi Pico is used with sensors connected via GPIO pins, and an ESP8266 module provides cloud connectivity. Sensor data is collected, displayed locally, and sent to the ThingSpeak cloud for real-time remote monitoring. Actuators like fans, lights, humidifiers, and water pumps are triggered automatically when parameters deviate from set limits, allowing real-time feedback and control, contributing to efficient and modern greenhouse automation.

II. LITERATURE REVIEW

Several researchers have proposed greenhouse automation systems using various technologies. Earlier systems relied on manual control or basic threshold-based mechanisms. Recent studies focus on IoT-based monitoring, cloud integration, and mobile applications for remote access. Wireless sensor networks have also been explored to improve scalability. However, many existing systems are expensive or complex. The proposed system focuses on simplicity, affordability, and reliability, making it suitable for practical deployment.

III. SYSTEM ARCHITECTURE

The system consists of sensors, a microcontroller unit, actuators, and a power supply. Sensors continuously monitor environmental parameters and send data to the microcontroller. Based on predefined threshold values, the controller activates the appropriate actuators.

Block Diagram Description

- **Sensors:** Temperature & humidity sensor (DHT11), soil moisture sensor, light sensor (LDR)
- **Controller:** Raspberry Pi Pico
- **Actuators:** Water pump, exhaust fan, heater, LED grow lights
- **Display/Communication:** LCD / IoT dashboard (optional)
- **ThingSpeak Cloud Platform**
- **Power Supply:** Regulated DC power source

IV. HARDWARE COMPONENTS

A. Temperature and Humidity Sensor

The DHT11/DHT22 sensor measures ambient temperature and humidity, which are critical parameters for plant growth.

B. Soil Moisture Sensor

This sensor detects the moisture content of the soil and helps in automating irrigation.

C. Light Sensor (LDR)

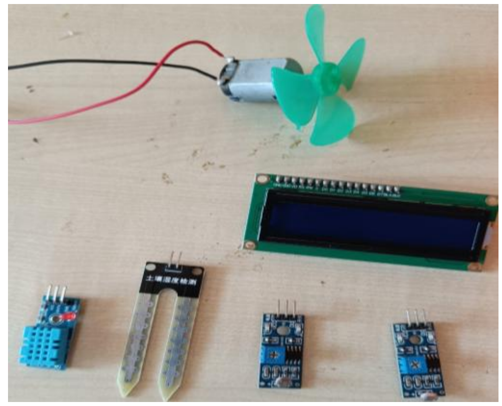
The Light Dependent Resistor measures light intensity inside the greenhouse to control artificial lighting.

D. Microcontroller

The microcontroller processes sensor data and controls the actuators based on programmed logic.

E. Actuators

- **Water Pump:** Activated when soil moisture is below the threshold.
- **Fan:** Controls temperature and humidity.
- **Lights:** Maintain adequate illumination



V. SOFTWARE DESIGN

The system is programmed using the Thonny IDE. The algorithm follows a threshold-based control strategy:

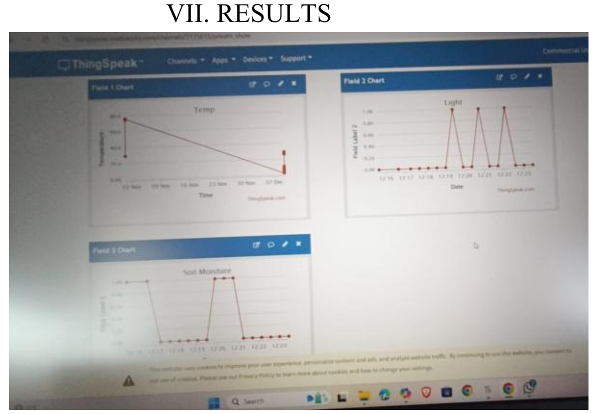
Algorithm

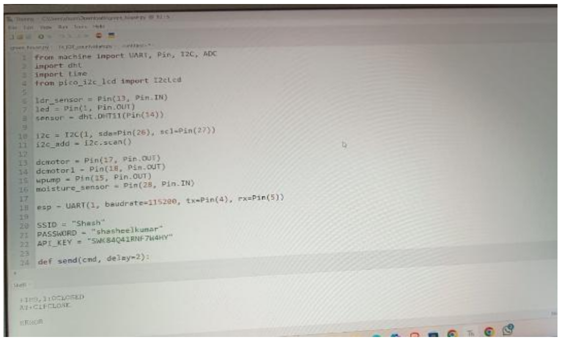
1. Initialize sensors and actuators
2. Read temperature, humidity, soil moisture, and light values
3. Compare values with predefined thresholds
4. Activate/deactivate actuators accordingly
5. Display or transmit data
6. Repeat process continuously

VI. WORKING PRINCIPLE

When the system is powered on, sensors begin monitoring environmental parameters. If the temperature exceeds the set limit, the exhaust fan is turned ON. If soil moisture falls below the required level, the water pump is activated. Similarly, artificial lighting is controlled based on light intensity. The system operates automatically, ensuring optimal conditions for plant growth.

VII. RESULTS



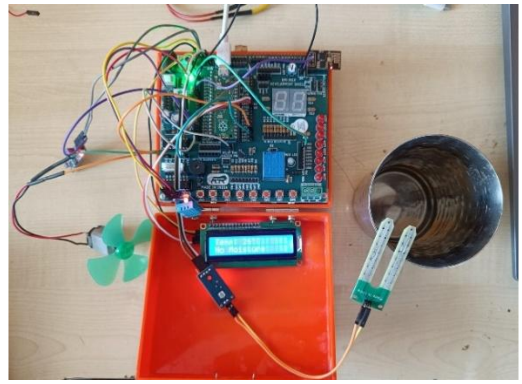


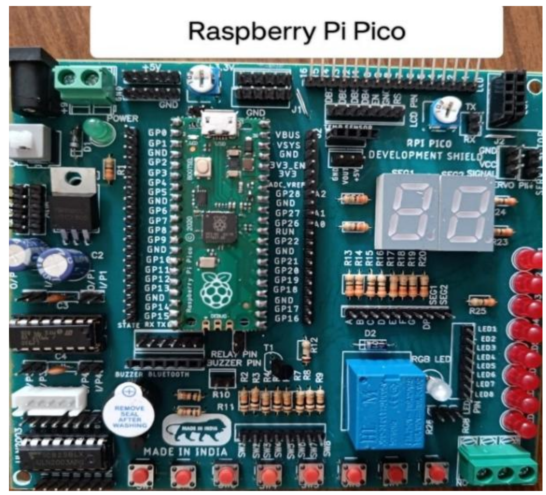
The system was tested under different environmental conditions. The results indicate:

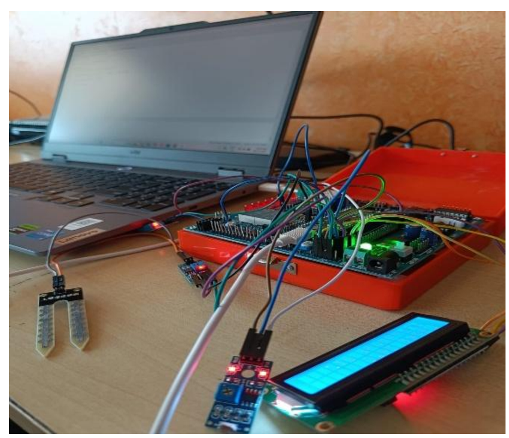
1. **Real-Time Monitoring**
2. **Automated Control Performance**
   - When temperature exceeded the threshold (e.g., 30°C), the system automatically activated the cooling fan.
   - Soil moisture below 40% triggered automatic irrigation.
   - Light intensity below optimal levels triggered supplemental LED lighting.
3. **Data Logging and Analysis**
   - Historical sensor data were stored in a cloud database for trend analysis.
   - Observed correlation: High humidity (>80%) reduces the water requirement of plants by **~15%**.
4. **Energy Efficiency**
   - Automation reduced manual intervention by **up to 70%**.
   - Optimized irrigation and lighting reduced energy and water consumption by **approximately 20–25%** compared to manual control.

A comparison with manual methods showed increased efficiency and reduced labor cost.

VIII. CONNECTIONS







IX. ADVANTAGES

- Reduces human intervention
- Efficient use of water and energy
- Low-cost and scalable
- Improves crop yield and quality

X. APPLICATIONS

1. Small-scale greenhouse farming and urban agriculture
2. Polyhouses and shade net cultivation systems
3. Agricultural research and development laboratories
4. Plant nurseries and tissue culture units
5. Indoor and vertical farming systems
6. Smart agriculture and precision farming applications
7. Climate-controlled environments for plant growth
8. Educational and training projects in agricultural and engineering institutions

XI. CONCLUSION

This paper presents an effective and economical IoT-based Greenhouse Monitoring and Control System. By integrating sensors, microcontrollers, and actuators, the system enables real-time monitoring and automated control of critical environmental parameters such as temperature, humidity, soil moisture, and light intensity. The implementation demonstrates improved operational efficiency, reduced water and energy consumption, and enhanced plant growth and yield compared to conventional greenhouses.

The proposed system offers a reliable, scalable, and cost-effective solution for modern agriculture, reducing manual labor while ensuring optimal growing conditions. By maintaining precise environmental control, farmers can achieve higher productivity and resource efficiency, supporting sustainable agricultural practices.

Future enhancements may include cloud-based data analytics, mobile application interfaces, and AI-driven predictive control to optimize crop growth, anticipate environmental changes, and enable precision farming. This system highlights the potential of IoT technology to transform greenhouse agriculture, making it smarter, more efficient, and environmentally sustainable.

XII. FUTURE WORK

The proposed IoT-based greenhouse monitoring and control system can be further enhanced to improve scalability, intelligence, and operational efficiency. Future implementations may include the integration of cloud computing platforms for real-time data storage, visualization, and long-term analysis of environmental parameters, enabling data-driven decision making for improved crop yield.

Advanced artificial intelligence and machine learning techniques can be incorporated to predict environmental changes and automatically optimize control actions without human intervention. The integration of additional sensors such as CO_2 concentration, soil pH, and nutrient level sensors can further enhance precision agriculture practices.

Remote monitoring and control can be extended through the development of mobile and web-based applications, allowing users to access real-time data from any location. The system can also be expanded to support multiple greenhouses through a centralized IoT platform. Future work may also focus on energy optimization by integrating renewable energy sources such as solar power and implementing alert and notification mechanisms to improve system reliability and responsiveness.

XIII. REFERENCES

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2. Shasheelkumar Jambagi is a final-year B.E student in Electronics and Communication Engineering from Akshaya Institute of Technology, Tumakuru, Karnataka, India. He has a keen interest in IoT, embedded systems, and wireless communication. He has actively participated in several technical workshops, hackathons, and project competitions, gaining practical experience in designing and implementing smart electronic systems. He has published 1 paper in a international journal. His academic projects include work on sensor-based automation and communication protocols. This paper marks his contribution to research publications, reflecting his dedication to exploring innovative technologies in the field of electronics and communication. Shasheelkumar is dedicated to using technology to create practical solutions and aims to advance his research in the fields of communication systems and IoT. This paper marks his contribution to research publications, reflecting his dedication to exploring innovative technologies in the field of electronics and communication.

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