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Green House Monitoring and Controlling System

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KEYWORDS

Arduino, Color Sorting System, Conveyor Belt Automation, TCS3200 Color Sensor, IR Proximity Sensor, Robotic Arm, Servo Motor, Industrial Automation, Embedded Systems, Pick-and-Place Mechanism

ABSTRACT

This project presents the design and implementation of an Arduino-based conveyor belt color sorting robotic system for industrial automation applications. The system is developed to automatically detect, classify, and sort objects based on their colour with minimal human intervention. A TCS3200 color sensor is used to identify the RGB values of objects moving on a conveyor belt driven by a DC motor. An IR proximity sensor detects the presence and position of objects at the sensing point to ensure synchronized operation. The Arduino microcontroller acts as the central control unit, processing sensor inputs and generating control signals for actuators. Based on the detected color, servo motors mounted on a robotic arm perform precise pick-and-place operations, placing objects into designated bins. The system also incorporates safety features such as an emergency stop push button and buzzer alert mechanism to enhance operational reliability and ensure user safety. Experimental evaluation demonstrates high sorting accuracy under controlled lighting conditions, consistent conveyor movement, and reliable robotic arm actuation. The proposed system offers a low-cost, scalable, and flexible automation solution suitable for small- and medium-scale industries, educational laboratories, and research environments. By reducing manual labor, improving accuracy, and enhancing productivity, the system contributes effectively to modern industrial automation.

INTRODUCTION

Greenhouse farming has become an essential component of modern agriculture as it enables crop cultivation under controlled environmental conditions, regardless of external climate variations. By regulating factors such as temperature, humidity, soil moisture, light intensity, and air quality, greenhouse systems help improve plant growth, increase crop yield, and ensure year-round agricultural production. However, maintaining these environmental parameters manually is difficult and often inefficient, particularly in large greenhouse facilities where continuous monitoring is required. Traditional methods rely heavily on human supervision, which may lead to delays in responding to environmental changes and can negatively affect plant health and productivity.

With the advancement of Internet of Things (IoT) technologies and wireless sensor networks, greenhouse monitoring systems have become more intelligent and automated. IoT-based systems allow multiple sensors to collect environmental data in real time and transmit it to centralized controllers for analysis and decision-making. Earlier studies have demonstrated the effectiveness of wireless sensor networks in greenhouse monitoring applications. For example, Jian Song proposed a greenhouse monitoring system based on Zigbee wireless sensor networks that enabled real-time environmental data collection and control mechanisms for greenhouse environments [1]. Similarly, IoT-based remote monitoring platforms using smartphones and internet connectivity have been introduced to provide efficient home and agricultural automation solutions [2].

Recent research has further emphasized the importance of integrating IoT gateways and sensor-based networks for agricultural greenhouse management. Guohong Li et al. designed an IoT gateway architecture to support communication between greenhouse sensors and remote monitoring platforms, enabling better data management and system scalability [3]. In addition, intelligent greenhouse monitoring systems based on IoT technologies have been proposed to automate environmental control using sensor data and embedded controllers [4]. Soil monitoring techniques have also been explored to ensure proper irrigation management and prevent water wastage in agricultural applications [5].

Advancements in IoT-based greenhouse automation systems have enabled more precise and intelligent environmental control. Several studies have proposed systems capable of monitoring temperature, humidity, soil moisture, and light intensity while automatically controlling irrigation, ventilation, and lighting mechanisms [7]–[10]. These systems demonstrate the potential of combining sensors, microcontrollers, and IoT platforms to enhance agricultural productivity and resource efficiency. Furthermore, recent research trends highlight the growing importance of greenhouse automation and controlled environment agriculture in achieving sustainable food production and smart farming practices [13], [15].

Motivated by these developments, this work proposes an IoT-enabled smart greenhouse monitoring and automation system using Raspberry Pi 3. The system integrates environmental sensors such as DHT11 for temperature and humidity measurement, an LDR sensor for light detection, a soil moisture sensor for irrigation monitoring, and a gas sensor for air quality detection. Based on the sensor data, the system automatically controls actuators including a DC fan for temperature and humidity regulation, a water pump for irrigation, a lighting system for maintaining proper illumination, and a servo-controlled ventilation mechanism for removing harmful gases. The collected data is displayed locally on an LCD module and transmitted to a mobile application through IoT connectivity, allowing farmers to monitor greenhouse conditions remotely. The overall architecture of the proposed smart greenhouse monitoring system is illustrated in Fig. 1.

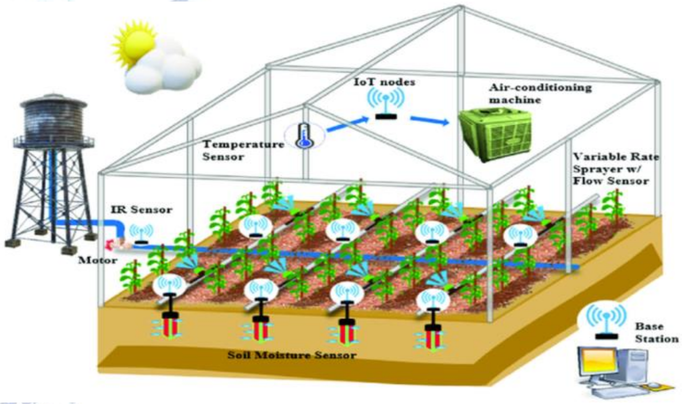

Figure 1 Conceptual architecture of the proposed system with IoT monitoring.

RELATED WORK

The development of intelligent greenhouse monitoring systems has attracted significant attention in recent years due to the growing need for efficient agricultural management and sustainable crop production. Various researchers have proposed different techniques using wireless sensor networks (WSN), Internet of Things (IoT), and embedded systems to automate greenhouse monitoring and environmental control.

One of the earlier approaches for greenhouse monitoring was presented by Jian Song [1], who proposed a greenhouse control system based on a Zigbee wireless sensor network. The system used distributed sensor nodes to monitor environmental parameters such as temperature and humidity and transmit data to a centralized control unit. This work demonstrated the feasibility of wireless sensor networks in agricultural monitoring and control applications.

With the emergence of IoT technologies, remote monitoring and control systems have become more advanced and accessible. Rajeev Piyare [2] introduced an IoT-based home monitoring and control system using an Android smartphone. Although primarily focused on home automation, the proposed architecture highlighted the potential of IoT-enabled devices for remote monitoring and real-time control, which can also be applied to agricultural environments.

To enhance connectivity and data communication in agricultural IoT systems, Guohong Li et al. [3] proposed an IoT gateway architecture for greenhouse applications. The gateway served as an interface between sensor networks and cloud platforms, enabling efficient data collection, processing, and remote monitoring. Similarly, Liu Dan et al. [4] developed an intelligent greenhouse monitoring system based on IoT technology that automatically collected environmental parameters and improved greenhouse management through automated control mechanisms.

Efficient soil monitoring and irrigation management are also crucial aspects of smart agriculture. Balakrishna et al. [5] proposed a real-time soil monitoring system that continuously measures soil conditions and helps optimize irrigation practices. In another study, Liu Dan et al. [6] introduced a precise agricultural greenhouse system that combined IoT technology with fuzzy control algorithms to maintain optimal environmental conditions within the greenhouse.

Several researchers have implemented greenhouse monitoring systems using microcontrollers and embedded platforms. Vimal and Shivaprakasha [7] developed an IoT-based greenhouse monitoring and control system using the Arduino platform. Their system monitored environmental parameters and controlled greenhouse devices such as irrigation systems and ventilation mechanisms. Similarly, Shah and Bhatt [8] designed a greenhouse automation system capable of monitoring temperature, humidity, and soil moisture while controlling irrigation and ventilation equipment.

Further improvements in greenhouse automation were introduced by Shenan et al. [9], who developed an intelligent IoT-based greenhouse monitoring system that integrated multiple sensors and automated environmental control mechanisms. Satpute et al. [10] also proposed an IoT-based greenhouse monitoring system that used sensors to measure environmental parameters and transmitted the collected data to a cloud platform for remote monitoring.

In addition, Jayaty et al. [11] presented a polyhouse monitoring and control system that automated greenhouse operations using IoT sensors and microcontrollers. Shinde and Siddiqui [12] proposed a wireless sensor network-based greenhouse monitoring system capable of detecting environmental changes and automatically controlling greenhouse equipment.

Recent studies have also highlighted the growing importance of automation and smart agriculture technologies in modern greenhouse management. Shamshiri et al. [13] provided a comprehensive review of greenhouse automation technologies and discussed the transition toward plant factories and controlled environment agriculture. Mythili et al. [14] proposed a smart farm monitoring system based on IoT that enables farmers to monitor agricultural conditions remotely using internet-connected devices.

Furthermore, research trends in greenhouse technologies indicate an increasing focus on sustainability, precision agriculture, and automated farming solutions. Aznar-Sánchez et al. [15] analyzed global research trends in greenhouse technology and emphasized the importance of integrating advanced technologies such as IoT and smart sensors to improve agricultural productivity and sustainability.

In addition to research studies, several hardware components and sensor technologies are widely used in greenhouse monitoring systems. Sensors such as humidity sensors [16], DHT11 temperature and humidity sensors [17], soil moisture sensors [18], and light-dependent resistors (LDR) [19] are commonly used to monitor environmental parameters. Communication modules such as ESP8266 NodeMCU enable IoT connectivity and data transmission to cloud platforms or mobile applications [20]. Moreover, modern communication platforms like Telegram bots can be integrated into IoT systems to provide real-time alerts and notifications to users [21].

Based on the existing literature, it is evident that IoT-based greenhouse monitoring systems offer significant advantages in terms of automation, efficiency, and remote accessibility. However, many existing systems focus on limited environmental parameters or lack integrated automation features. Therefore, this work proposes an IoT-enabled smart greenhouse monitoring and control system using Raspberry Pi, which integrates multiple environmental sensors and automated control mechanisms to improve greenhouse management and agricultural productivity.

PROPOSED SYSTEM

The proposed system presents an IoT-based smart greenhouse monitoring and automation system using Raspberry Pi 3 to maintain optimal environmental conditions for plant growth. The system continuously monitors key parameters such as temperature, humidity, soil moisture, light intensity, and gas concentration using multiple sensors. Based on the sensor readings, the system automatically controls various actuators to regulate the greenhouse environment. In addition, the collected data is transmitted to a mobile application through IoT connectivity, allowing farmers to monitor greenhouse conditions remotely.

In the proposed architecture, Raspberry Pi 3 acts as the central processing unit that receives data from all sensors and processes the information to control the actuators accordingly. The DHT11 sensor measures temperature and humidity levels inside the greenhouse, while the LDR sensor detects the intensity of light available for plant growth. A soil moisture sensor monitors the water content in the soil to determine whether irrigation is required. Additionally, a gas sensor is used to detect harmful gases that may affect plant health.

Based on the collected sensor data, the Raspberry Pi automatically controls several actuators to maintain optimal conditions. A DC fan is activated when the temperature or humidity exceeds the predefined threshold to maintain proper airflow and cooling. When the light intensity drops below a certain level, an artificial light source is turned on to ensure sufficient illumination for plant growth. Similarly, the water pump is activated when the soil moisture level falls below the required threshold to maintain adequate irrigation. In the presence of harmful gases, a servo motor is used to open a ventilation flap, allowing fresh air to circulate inside the greenhouse.

To provide local monitoring, an LCD display is integrated into the system to show real-time sensor readings such as temperature, humidity, soil moisture, and light intensity. Furthermore, the environmental data collected by the sensors is transmitted through an IoT communication module to a mobile application, enabling farmers to monitor greenhouse conditions remotely and take necessary actions when required.

The proposed system improves greenhouse management by providing real-time monitoring, automated environmental control, reduced manual labor, and efficient resource utilization. The overall architecture of the proposed greenhouse monitoring and automation system is illustrated in Fig. 2.

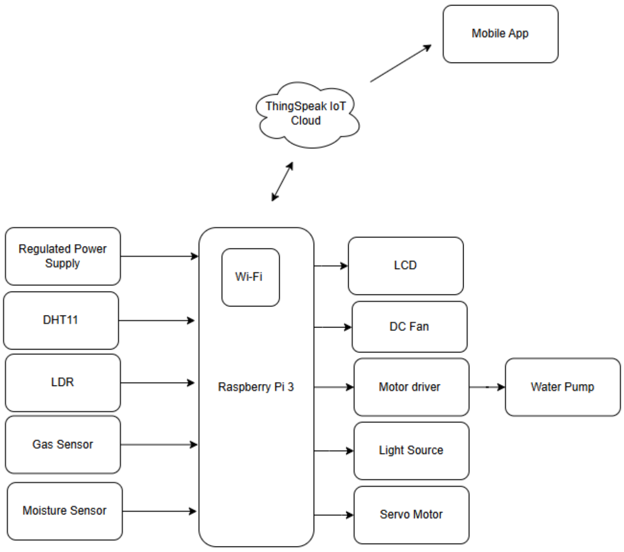

Figure 2 Block diagram of the proposed system with feedback and IoT.

METHODOLOGY

The proposed smart greenhouse monitoring and automation system operates by continuously sensing environmental parameters and automatically controlling actuators to maintain optimal conditions for plant growth. The methodology involves sensor data acquisition, data processing using Raspberry Pi 3, decision making based on predefined thresholds, actuator control, and IoT-based data transmission for remote monitoring.

A. Sensor Data Acquisition

The system integrates multiple sensors to monitor different environmental parameters inside the greenhouse. The DHT11 sensor measures temperature and humidity, the LDR sensor detects light intensity, the soil moisture sensor monitors the water content in the soil, and the gas sensor detects the presence of harmful gases. These sensors continuously collect environmental data and send the readings to the Raspberry Pi controller.

The temperature and humidity values are obtained using the DHT11 sensor, which provides digital output signals that can be directly processed by the Raspberry Pi. Soil moisture levels are measured using an analog sensor that determines the water content in soil based on electrical conductivity. Similarly, the LDR sensor measures the intensity of light by varying its resistance depending on the amount of light falling on it.

B. Data Processing and Decision Making

Once the sensor data is collected, the Raspberry Pi processes the information and compares the values with predefined threshold levels. Based on these thresholds, appropriate control actions are taken to regulate greenhouse conditions.

For example:

- If the temperature exceeds the threshold value, the cooling system (DC fan) is activated.
- If light intensity is low, an artificial light source is turned on.
- If soil moisture is below the required level, the irrigation pump is activated.
- If harmful gases are detected, the ventilation flap controlled by a servo motor is opened.

These automated responses ensure that the greenhouse environment remains within optimal limits required for plant growth.

C. Working Algorithm

The working procedure of the proposed greenhouse monitoring system is summarized in Algorithm 1.

```
Algorithm 1: Smart Greenhouse Monitoring and Control

Step 1: Start the system
Step 2: Initialize Raspberry Pi, sensors, LCD display, and actuators
Step 3: Read temperature and humidity from DHT11 sensor
Step 4: Read light intensity from LDR sensor
Step 5: Read soil moisture level from soil moisture sensor
Step 6: Read gas level from gas sensor

Step 7: Display sensor readings on LCD

Step 8: If temperature > threshold
            Turn ON DC fan
        Else
            Turn OFF DC fan

Step 9: If light intensity < threshold
            Turn ON artificial light
        Else
            Turn OFF light

Step 10: If soil moisture < threshold
             Turn ON water pump
         Else
             Turn OFF water pump

Step 11: If gas level > threshold
             Rotate servo motor to open ventilation
         Else
             Keep ventilation closed

Step 12: Send sensor data to mobile application via IoT

Step 13: Repeat steps 3-12 continuously
Step 14: End
```

D. Actuator Control

The system uses several actuators to regulate environmental conditions:

- DC Fan: Controls temperature and humidity.
- Water Pump: Maintains adequate soil moisture through automated irrigation.
- Artificial Light: Provides additional illumination when natural light is insufficient.
- Servo Motor: Opens ventilation flaps when harmful gases are detected.

The Raspberry Pi sends control signals to these actuators through GPIO pins based on the processed sensor data.

E. IoT-Based Remote Monitoring

In addition to local control, the system transmits real-time environmental data to a mobile application using IoT connectivity. Farmers can monitor greenhouse parameters remotely and receive updates about system status. This feature enables efficient greenhouse management and reduces the need for constant physical monitoring.

F. System Workflow

The methodology ensures that the greenhouse operates autonomously by continuously sensing environmental conditions, processing the data using Raspberry Pi, and activating appropriate control mechanisms. This automated process improves crop growth conditions, reduces manual intervention, and enhances the efficiency of greenhouse farming through intelligent monitoring and real-time environmental control.

RESULTS AND DISCUSSIONS

The proposed IoT-based smart greenhouse monitoring and automation system was implemented and tested using a Raspberry Pi 3 along with environmental sensors and actuators. The prototype system successfully monitored and controlled greenhouse parameters such as temperature, humidity, soil moisture, light intensity, and gas concentration in real time. The results demonstrate that the system is capable of maintaining optimal environmental conditions for plant growth while minimizing manual intervention.

The hardware prototype integrates multiple sensors including DHT11 for temperature and humidity sensing, LDR for light intensity detection, soil moisture sensor for irrigation monitoring, and a gas sensor for detecting harmful gases. These sensors continuously send environmental data to the Raspberry Pi controller. Based on the received data, the controller activates appropriate actuators such as a DC fan, water pump, artificial light source, and servo motor ventilation system.

The developed prototype of the greenhouse monitoring system is shown in Fig. 3. The system consists of the Raspberry Pi board connected with different sensors and actuators that are placed inside the greenhouse environment to monitor plant growth conditions. The LCD module displays real-time readings of environmental parameters, allowing users to observe system performance locally.

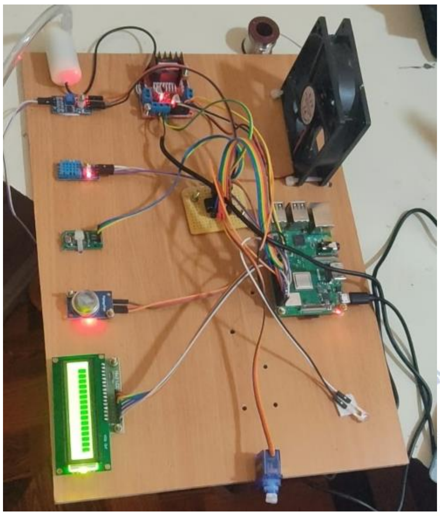

Figure 3 Hardware prototype of the IoT-based smart greenhouse monitoring system.

The experimental results show that the system responds effectively to environmental changes. When the temperature or humidity level exceeds the predefined threshold, the DC fan is automatically activated to maintain suitable environmental conditions. Similarly, when the soil moisture level drops below the required level, the water pump is turned on to irrigate the plants. When light intensity decreases, the artificial lighting system is activated to ensure adequate illumination for plant growth. In addition, the servo motor operates a ventilation flap when harmful gases are detected, allowing fresh air circulation inside the greenhouse.

Figure 4 LCD display showing real-time environmental parameters.

The LCD display showing the real-time environmental parameters is illustrated in Fig. 4. The display provides continuous updates of sensor readings, including temperature, humidity, soil moisture, and light levels. This feature helps farmers or greenhouse operators easily observe environmental conditions without accessing external monitoring systems.

Furthermore, the system also supports remote monitoring through IoT connectivity, allowing environmental data to be transmitted to a mobile application or cloud platform. This enables users to monitor greenhouse conditions from remote locations and take necessary actions when required. The remote monitoring interface is illustrated in Fig. 5, where sensor readings are displayed on a mobile device.

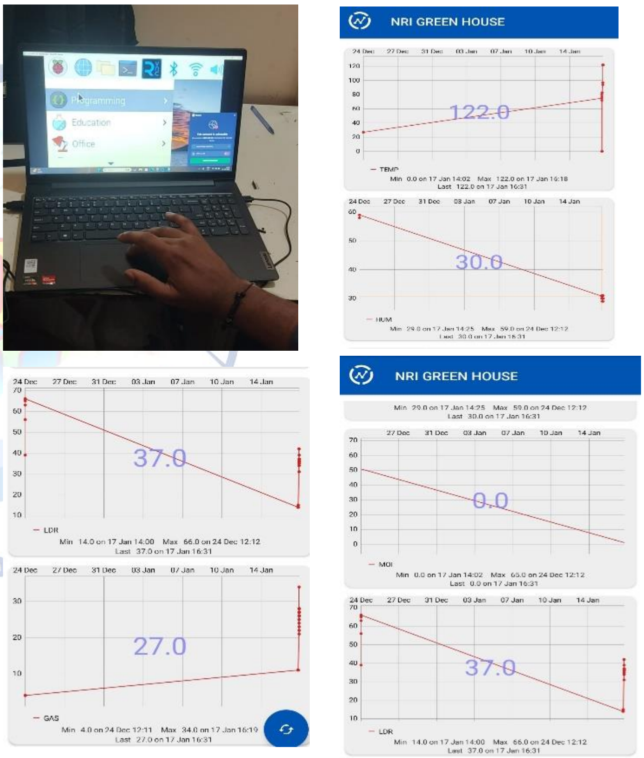

Figure 5 Remote monitoring of greenhouse parameters using IoT-based mobile interface.

The experimental evaluation confirms that the proposed system effectively automates greenhouse environmental control. By continuously monitoring environmental parameters and automatically activating appropriate actuators, the system improves plant growth conditions, reduces manual labor, and optimizes resource utilization. The results demonstrate that the proposed IoT-based smart greenhouse monitoring system can serve as an efficient and cost-effective solution for modern precision agriculture.

CONCLUSION

In this work, an IoT-based smart greenhouse monitoring and automation system using Raspberry Pi 3 has been successfully designed and implemented to improve the efficiency of greenhouse farming. The proposed system integrates multiple environmental sensors such as DHT11 for temperature and humidity monitoring, LDR for light intensity detection, soil moisture sensor for irrigation monitoring, and a gas sensor for detecting harmful gases. These sensors continuously collect environmental data and transmit it to the Raspberry Pi controller for processing and decision-making.

Based on the sensed parameters, the system automatically controls different actuators including a DC fan for regulating temperature and humidity, a water pump for automated irrigation, an artificial lighting system for maintaining adequate illumination, and a servo motor for ventilation control when harmful gases are detected. Additionally, an LCD display provides real-time monitoring of environmental conditions within the greenhouse, while IoT connectivity enables remote monitoring through a mobile application.

The experimental results demonstrate that the proposed system effectively maintains optimal greenhouse conditions by continuously monitoring environmental parameters and automatically responding to changes. This automation significantly reduces manual labor, improves resource utilization such as water and energy, and ensures better crop growth conditions.
Overall, the proposed system offers a cost-effective, reliable, and scalable solution for smart agriculture and precision farming. By combining IoT technology with automated environmental control, the system enhances greenhouse productivity and supports sustainable agricultural practices. Future improvements may include integrating machine learning techniques for predictive crop management, cloud-based data analytics, and advanced sensors for more accurate environmental monitoring, further enhancing the efficiency of smart greenhouse systems.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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