An IoT-Based Monitoring and Control System for Chrysanthemum Cultivation

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Abstract—Chrysanthemum cultivation in greenhouse environments requires stable control of environmental conditions, particularly air temperature, light intensity, and soil moisture, to ensure optimal plant growth. However, conventional manual monitoring and control methods still face limitations in terms of efficiency and accuracy. This study aims to design and implement an Internet of Things (IoT)-based monitoring and control system for chrysanthemum cultivation using the NodeMCU ESP8266 microcontroller. The system is equipped with a DHT22 sensor for air temperature, a BH1750 sensor for light intensity, and a capacitive soil moisture sensor v2. Measurement data are transmitted in real time to a Firebase Realtime Database and displayed through the ChrysoSmart mobile application, which supports both automatic and manual operating modes. System testing was conducted directly in a chrysanthemum greenhouse to evaluate sensor performance, actuator operation, and data communication stability. The test results indicate that the system is capable of real-time monitoring and control of greenhouse environmental conditions, with average sensor errors of 0.99% for temperature, 1.11% for light intensity, and 2.96% for soil moisture. The actuators, including a water pump, lighting system, and exhaust fan, operated properly according to system logic and user commands. Therefore, the ChrysoSmart system is considered feasible and effective for supporting automated and remote environmental management in chrysanthemum greenhouse cultivation.

Keywords— Chrysanthemum cultivation, Internet of Things (IoT), greenhouse monitoring, smart agriculture, environmental control

1. Introduction

Chrysanthemum is one of the most popular ornamental plants with high economic value and is widely cultivated in Indonesia. However, chrysanthemum plants are highly sensitive to environmental conditions, particularly light intensity, air temperature, and soil moisture. The success of chrysanthemum cultivation strongly depends on the stability of these environmental factors, especially during the vegetative growth and flowering stages [1].

Conventional chrysanthemum cultivation in greenhouses still faces various challenges, such as difficulties in regulating irrigation and maintaining optimal moisture levels, particularly on a large scale. Inaccurate watering practices can not only inhibit plant growth but also promote the development of fungi and bacteria [2]. In addition, many farmers still rely on manual systems for irrigation and lighting control, which are prone to timing errors and may reduce flower quality and productivity [3].

To improve efficiency, accuracy, and productivity in chrysanthemum cultivation, the adoption of technologies capable of automating plant maintenance processes is required [4]. One technology that can be effectively applied in chrysanthemum cultivation is the Internet of Things (IoT), which enables the interconnection and remote control of devices through internet-based communication [3]. The implementation of IoT technology plays an important role in improving cultivation efficiency and reducing dependence on human labor, thereby minimizing errors in plant care activities [4].

This study aims to design and implement an IoT-based monitoring and control system for chrysanthemum cultivation in a greenhouse environment. The proposed system is capable of monitoring and controlling three main environmental parameters: light intensity, air temperature, and soil moisture in both automatic and manual operating modes. The system is expected to maintain optimal growing conditions, thereby improving the quality and quantity of chrysanthemum production. Furthermore, this research is expected to provide practical benefits for farmers and agribusiness practitioners while contributing to the development of smart farming technologies based on IoT.

2. Literature Review

Research related to monitoring and controlling environmental conditions in chrysanthemum cultivation has been conducted by various researchers using different approaches, parameters, and technologies.

Cahyono et al. (2021) developed a monitoring and humidity control system for chrysanthemum greenhouses using the Telegram platform. Their results showed that the system was capable of managing humidity and temperature automatically [5].

Nuraini et al. (2022) designed a Smart Agro System for chrysanthemum cultivation in areas without internet access. The system utilized Bluetooth communication to monitor soil moisture, plant height, and to control lighting and irrigation [6].

Parma et al. (2024) implemented an IoT-based greenhouse system using DHT22 and soil moisture sensors connected to an ESP8266 microcontroller and the Blynk application. The system successfully controlled temperature and soil moisture using pump and solenoid actuators, with monitoring results displayed on a TFT LCD [2].

Habi et al. (2023) developed a control system for temperature and light intensity in chrysanthemum cultivation using Arduino and NodeMCU. The system supported both manual and automatic modes for temperature regulation, lighting, and irrigation through the Blynk application [7].

Based on the reviewed studies, this research develops an IoT-based monitoring and control system for chrysanthemum cultivation using the NodeMCU ESP8266 microcontroller, a DHT22 sensor for air temperature and humidity measurement, a BH1750 sensor for light intensity detection, and a capacitive soil moisture sensor v2 for soil moisture measurement. The system utilizes a mobile application as a monitoring and control interface, with cloud-based data synchronization to support real-time and remote greenhouse management.

3. Research Methodology

This study employed an experimental research approach to design, develop, and evaluate an Internet of Things (IoT)-based monitoring and control system for chrysanthemum cultivation in a greenhouse environment. The research methodology was structured to ensure that each stage, from system design to field testing, accurately reflected real operational conditions in chrysanthemum cultivation practices.

The research process consisted of three main components: (1) determination of the research location and formulation of the overall system framework, (2) development of the IoT-based monitoring and control system, and (3) testing and evaluation of system performance. The prototyping model used in the system development process is illustrated in Figure 1.

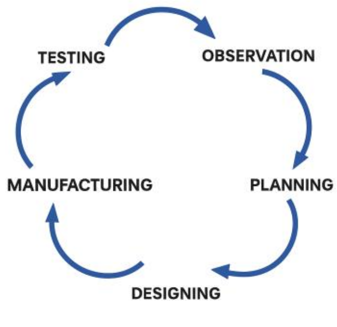

Fig 1. Prototyping model used in system development

The system development was conducted using a prototyping model, which involves iterative stages including observation, planning, system design, implementation, and testing [8]. This model was selected because it supports continuous system refinement based on evaluation results and user feedback, ensuring that the developed system meets the specified functional and performance requirements.

In general, the system development stages focused on observation, planning, and system design, as described in this research methodology section. System implementation and prototype performance testing were carried out directly in the greenhouse environment, and the results are presented and discussed in the Results and Discussion section. The overall development flow using the prototyping model is shown in Figure 1, which illustrates the iterative relationship among the system development stages.

3.1 Observation

The observation stage was conducted to identify environmental parameters that influence plant growth and to analyze user requirements related to a remote monitoring and control system for irrigation, lighting, and air circulation. Field observations were carried out in a chrysanthemum greenhouse located in Karanglo Village, Bandungan District, Semarang Regency.

Additional observations were also conducted at the Electronics Engineering Laboratory of Politeknik Negeri Semarang to study and evaluate the feasibility of the proposed system from a technical perspective. Furthermore, discussions with farmers and field practitioners were carried out to gain a deeper understanding of operational needs and real cultivation practices. The results of the observations and discussions in this stage served as the basis for determining the specifications of the system's hardware and software components.

3.2 Planning

During the planning stage, the research team defined system requirements and selected the required hardware and software components based on the observation results. The hardware planning included the use of a DHT22 sensor for air temperature and humidity measurement, a BH1750 sensor for light intensity measurement, and a capacitive soil moisture sensor v2 for soil moisture detection. The NodeMCU ESP8266 microcontroller was selected as the main controller to manage data acquisition, communication, and actuator control processes.

For software planning, Firebase Realtime Database was chosen as the cloud platform for real-time data storage and synchronization, while the monitoring and control application was developed using the Flutter framework. This stage also involved designing the data flow structure from sensors to the cloud server, configuring Wi-Fi communication, and defining system evaluation criteria, including sensor measurement accuracy, actuator response time, and system reliability in maintaining stable environmental conditions for chrysanthemum cultivation.

3.3 System Design

3.3.1 Hardware System Design

The overall architecture of the IoT-based monitoring and control system for chrysanthemum cultivation developed in this study is shown in Figure 2. The architecture integrates both hardware and software components to support environmental monitoring, data communication, and real-time actuator control within the greenhouse.

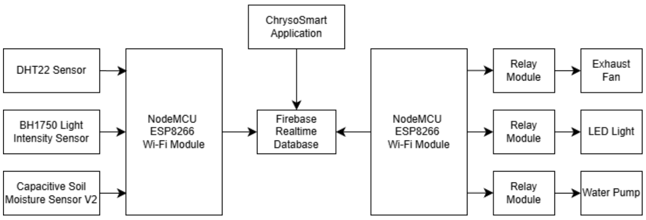

Fig 2. Block diagram of the IoT-based monitoring and control system for chrysanthemum cultivation

The system continuously monitors environmental parameters, including air temperature and humidity using the DHT22 sensor, light intensity using the BH1750 sensor, and soil moisture using the capacitive soil moisture sensor v2. All sensors are connected to the NodeMCU ESP8266 microcontroller, which functions as the main control unit.

The measured data are transmitted to the Firebase Realtime Database as a cloud-based server, allowing data to be synchronized and accessed in real time through the user application. In addition to monitoring, the system is equipped with a relay module to control actuators such as a water pump, LED lighting, and an exhaust fan. The actuators operate automatically based on predefined threshold values or can be controlled manually via the mobile application.

To provide a more detailed representation of the physical connections, power supply flow, and data communication paths, the complete system configuration is illustrated in Figure 3.

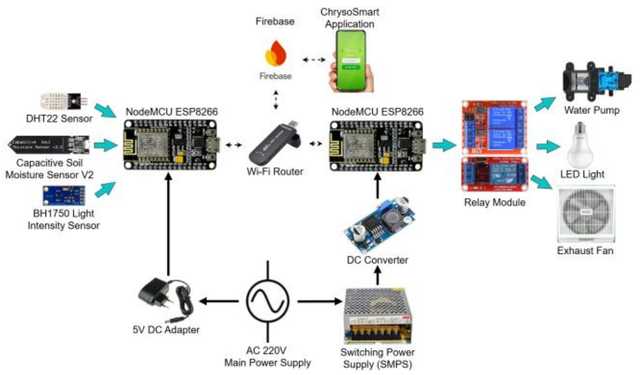

Fig 3. Configuration diagram of the IoT-based monitoring and control system for chrysanthemum cultivation

In this configuration, the NodeMCU ESP8266 on the sensor node side is powered by a DC adapter and is responsible for reading environmental sensor data and transmitting it to the Firebase Realtime Database via a Wi-Fi and internet connection. The NodeMCU ESP8266 on the actuator node side receives power from an AC source that is converted using an SMPS and DC converter to meet the system's voltage requirements.

The actuator node communicates with Firebase through the same Wi-Fi network, enabling real-time synchronization of data and control commands. The actuator node then controls the relay module to activate or deactivate the water pump, LED lighting, and exhaust fan according to environmental conditions or user commands from the application.

Overall, this system configuration is designed to ensure stable, integrated, and real-time monitoring and control of the greenhouse environment, allowing chrysanthemum growth parameters to be maintained under optimal conditions efficiently and sustainably.

3.3.2 Application System Design

The ChrysoSmart application was developed as the user interface to support IoT-based monitoring and control of chrysanthemum cultivation. The application serves as a communication bridge between users and the greenhouse system through the Firebase Realtime Database, enabling real-time access to sensor data and actuator status via smartphones. The main interface of the ChrysoSmart application is shown in Figure 4.

On the main screen, users are provided with two operation modes: automatic mode and manual mode. This mode selection is designed to offer flexibility in system management according to user needs. Automatic mode operates the system based on predefined parameters and threshold values, while manual mode allows direct user control.

Fig 4. Main interface of the ChrysoSmart application

In automatic mode, the application displays time and date information as synchronization indicators, along with real-time sensor readings including air temperature, light intensity, and soil moisture. These values are continuously updated from Firebase, allowing users to monitor greenhouse conditions remotely. The application also displays the status of system outputs such as the fan, lighting, and water pump, indicating whether each actuator is active based on automatic system decisions. The automatic mode interface is shown in Figure 5.

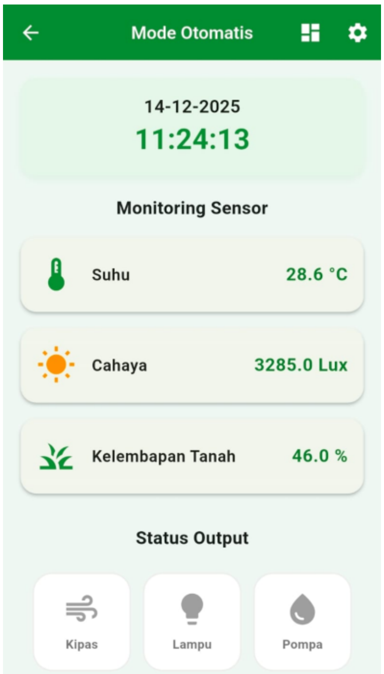

Fig 5. Automatic mode interface of the ChrysoSmart application

In manual mode, the application provides digital switch controls to individually operate the fan, lighting, and water pump. Any change in switch status is transmitted to Firebase and forwarded to the actuator node to control the relay modules according to user commands. This mode is typically used for system testing or specific environmental adjustments within the greenhouse. The manual mode interface is shown in Figure 6.

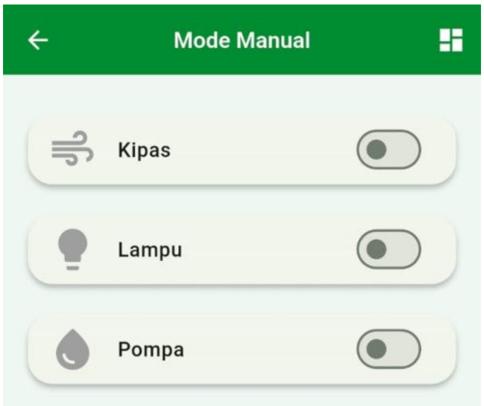

Fig 6. Manual mode interface of the ChrysoSmart application

The ChrysoSmart application interface was designed to be simple and intuitive, presenting essential information in a concise and visual manner. Integration with the Firebase Realtime Database enables two-way communication between users and the IoT system, allowing monitoring and control processes to be carried out quickly, responsively, and efficiently. Through this application, greenhouse environmental management for chrysanthemum cultivation can be performed remotely and in a centralized manner using mobile devices.

4. Results and Discussion

This section presents the results of system implementation and testing of the ChrysoSmart system as part of the prototyping process.

4.1 System Implementation Results

The implementation results indicate that the ChrysoSmart system was successfully realized and deployed directly in a chrysanthemum cultivation greenhouse. The developed system integrates sensor nodes, actuator nodes, the Firebase cloud server, and a mobile application into a unified Internet of Things (IoT) system that operates in real time.

The sensor node was installed inside the greenhouse at a position that adequately represents plant environmental conditions. This node consists of a NodeMCU ESP8266 microcontroller connected to DHT22, BH1750, and capacitive soil moisture sensor v2 to measure air temperature and humidity, light intensity, and soil moisture, respectively. The installation of the sensor node in the greenhouse environment is shown in Figure 7, demonstrating that the device was properly installed and operated during field testing.

Fig 7. Implementation of the ChrysoSmart sensor node installed in the chrysanthemum greenhouse

In addition to the sensor node, the system is equipped with a control panel that serves as the actuator control center. The control panel contains a NodeMCU ESP8266, relay module, power supply, and supporting components used to control the water pump, lighting, and exhaust fan. The control panel was installed in a secure and accessible area of the greenhouse to facilitate monitoring and maintenance. The installed control panel is shown in Figure 8.

Fig 8. ChrysoSmart control panel installed in the greenhouse for actuator control

During the implementation and field-testing stages, both the sensor node and control panel operated stably. Sensor data were successfully transmitted to the Firebase Realtime Database via Wi-Fi and displayed on the ChrysoSmart application. The actuators were also controlled effectively in both automatic and manual modes. These results indicate that the ChrysoSmart system has been successfully implemented both physically and functionally to support monitoring and control of greenhouse environmental conditions for chrysanthemum cultivation.

4.2 Sensor Testing Results

Sensor testing was conducted to evaluate the accuracy and stability of the ChrysoSmart system in monitoring environmental conditions within the chrysanthemum greenhouse. The tested sensors included the DHT22 sensor for air temperature and humidity, the BH1750 sensor for light intensity, and the capacitive soil moisture sensor v2. Testing was carried out directly in the greenhouse, and the sensor readings were displayed in real time through the ChrysoSmart mobile application.

The temperature sensor testing results indicate that air temperature conditions inside the greenhouse varied according to changes in time and solar radiation intensity. Both the minimum and maximum temperature values could be monitored reliably by the system. The BH1750 light intensity sensor was able to clearly detect variations in illumination levels under both low and high light conditions. Meanwhile, the capacitive soil moisture sensor v2 showed consistent changes in readings before and after the irrigation process, indicating its suitability as a control reference for automatic pump operation. A summary of the sensor testing results is presented in Table 1.

Table 1. Summary of Sensor Testing Results

Sensor	Parameter	Minimum Value	Maximum Value	Value
DHT22	Air temperature	23,4	56,2	ºC
BH1750	Light intensity	1	20.388	lux
Capacitive Soil Moisture Sensor V2	Soil moisture	31	90	%

Based on Table 1, all sensors were able to represent changes in the greenhouse environmental conditions effectively. The temperature and light intensity values showed variations that were consistent with actual field conditions, while soil moisture values increased after the irrigation process and gradually decreased over time.

To evaluate sensor accuracy, an error analysis was conducted by comparing sensor readings with reference measurement instruments. The error value was calculated as the percentage difference between the sensor readings and the reference values. A summary of the sensor error results is presented in Table 2.

Table 2. Summary of sensor error values

Sensor	Parameter	Minimum Error (%)	Maximum Error (%)	Average Error (%)
DHT22	Air temperature	0	2,99	0,99
BH1750	Light intensity	0,67	1,92	1,11
Capacitive Soil Moisture Sensor V2	Soil moisture	0	6,25	2,96

Based on Table 2, the DHT22 sensor demonstrated good accuracy with an average error of 0.99%, which is within acceptable tolerance limits for greenhouse temperature monitoring applications. The BH1750 sensor exhibited an average error of 1.11%, indicating that it is capable of measuring light intensity with sufficient accuracy, despite being influenced by natural lighting variations inside the greenhouse.

Meanwhile, the capacitive soil moisture sensor v2 showed an average error of 2.96%, with a maximum error reaching 6.25%. This error level is still acceptable for threshold-based irrigation control applications. The observed error is mainly influenced by variations in soil composition, density, and water distribution, which affect the dielectric properties measured by capacitive sensors. Nevertheless, the sensor provides sufficiently reliable readings for automatic irrigation decision-making in greenhouse cultivation.

Overall, the error analysis results indicate that all sensors used in the ChrysoSmart system possess adequate accuracy and are suitable for use as data sources in an IoT-based greenhouse monitoring and control system for chrysanthemum cultivation.

4.3 Actuator Testing Results

Actuator testing was conducted to evaluate the performance of the ChrysoSmart system in controlling output devices based on sensor data and mobile application commands. The tested actuators included the water pump, lighting, and exhaust fan, controlled through relay modules by the NodeMCU ESP8266. Testing was performed in two operating modes: automatic mode and manual mode, to ensure that all control functions operated as designed.

In automatic mode, actuators were controlled based on environmental parameter threshold values obtained from sensor readings. The water pump was activated when soil moisture fell below the predefined threshold and automatically turned off after the irrigation duration elapsed. The lighting and exhaust fan were controlled based on greenhouse light intensity and air temperature conditions. Test results showed that all actuators responded appropriately to environmental changes and operated according to system logic.

In manual mode, users were able to control actuators directly through the ChrysoSmart application. ON and OFF commands issued via the application were successfully received by the system and transmitted to the relay modules to activate or deactivate the actuators. No functional failures were observed during manual control testing for the water pump, lighting, or exhaust fan. A summary of actuator testing results in both operating modes is presented in Table 3.

Table 3. Summary of actuator testing results in automatic and manual modes

Actuator	Automatic Mode	Manual Mode	Description
Water pump	Activated when soil moisture < threshold	ON/OFF as commanded	Operated normally
Lighting	Activated according to scheduled time	ON/OFF as commanded	Operated normally
Exhaust fan	Activated when air temperature > threshold	ON/OFF as commanded	Operated normally

Based on Table 3, all actuators demonstrated appropriate responses in both automatic and manual modes. The system response time to control commands was relatively fast during field testing, indicating that the ChrysoSmart control system performed effectively in managing greenhouse support devices for chrysanthemum cultivation.

4.4 System and Application Performance

Based on the field testing conducted in the chrysanthemum greenhouse, the performance of the ChrysoSmart system was evaluated using several main parameters, namely sensor measurement accuracy, system response to environmental condition changes, and the stability of data and application communication. This evaluation was carried out to ensure that the system is capable of operating properly under real operational conditions.

The test results indicate that the system is able to measure environmental parameters with a good level of accuracy. The average error values of the temperature, light intensity, and soil moisture sensors remain within acceptable tolerance limits for greenhouse environmental monitoring applications. Therefore, the generated data are considered reliable and suitable as a basis for decision-making in the automatic control system. This level of accuracy supports the stable operation of the water pump, lighting system, and exhaust fan in accordance with the predefined control logic.

In terms of system responsiveness, the ChrysoSmart application is able to respond quickly and consistently to changes in environmental conditions as well as to user commands. In automatic mode, the system can process sensor data and execute actuator control actions without significant delay. Meanwhile, in manual mode, ON and OFF commands issued through the application can be properly executed by the actuators, allowing users to directly control the devices when necessary.

The performance of data communication between the sensor nodes, Firebase Realtime Database, and the ChrysoSmart application also demonstrates good stability throughout the testing process. Sensor data can be displayed in real time on the application, and two-way synchronization between the system and the application runs smoothly. This indicates that the implemented communication architecture is capable of supporting continuous and reliable monitoring and control operations.

4.5 Discussion

The results of this study indicate that the ChrysoSmart system based on the Internet of Things (IoT) can operate effectively and stably in a chrysanthemum greenhouse environment. The system is capable of performing real-time monitoring of environmental parameters and controlling supporting devices through both automatic and manual modes. The integration between sensor nodes, Firebase Realtime Database, and the ChrysoSmart application enables remote monitoring and control with a high level of stability throughout field testing.

From a technical perspective, the sensor testing results show that the obtained error values remain within acceptable tolerance limits for agricultural applications. The DHT22 and BH1750 sensors demonstrate adequate accuracy in monitoring temperature and light intensity, respectively. Although the capacitive soil moisture sensor v2 exhibits a higher error value compared to the other sensors, it is still considered suitable for threshold-based irrigation control, considering its sensitivity to soil moisture variations and environmental conditions.

The actuator control system also exhibits satisfactory performance. The water pump, lighting system, and exhaust fan operate according to the designed control logic, whether based on environmental conditions or predefined time scheduling. The system's ability to support both automatic and manual operating modes provides flexibility and convenience for users in managing greenhouse conditions according to the specific requirements of chrysanthemum cultivation.

In terms of overall system and application performance, data communication between the sensor nodes, Firebase platform, and the ChrysoSmart application remains stable during field testing. Sensor data are displayed in real time, and control commands can be executed without noticeable interruption. However, the system still depends on the quality of the internet connection, which may lead to potential data transmission delays under suboptimal network conditions.

Overall, the ChrysoSmart system not only offers technical benefits in monitoring and controlling the greenhouse environment but also provides operational advantages by reducing the need for manual monitoring and improving the efficiency of chrysanthemum cultivation management. Nevertheless, further development is still required, particularly in the application of historical data analysis or artificial intelligence techniques to enhance environmental condition prediction capabilities, as well as the integration of alternative backup power systems to improve long-term system reliability.

5. Conclusion

Based on the results of the design, implementation, testing, and analysis of the IoT-based monitoring and control system for chrysanthemum cultivation, the following conclusions can be drawn:

1) The developed system successfully achieved the research objectives by enabling real-time monitoring of key greenhouse environmental parameters, including air temperature, light intensity, and soil moisture, using DHT22, BH1750, and capacitive soil moisture sensor v2 integrated with the NodeMCU ESP8266 microcontroller and Firebase Realtime Database.
2) The sensor measurement accuracy remains within acceptable tolerance limits for agricultural applications. The DHT22, BH1750, and capacitive soil moisture sensor v2 exhibited average errors of 0.99%, 1.11%, and 2.96%, respectively, indicating that the sensors are suitable as reliable data sources for greenhouse environmental monitoring and control.
3) The actuator control system operates effectively in both automatic and manual modes. The water pump, exhaust fan, and lighting system function according to soil moisture conditions, air temperature, and predefined scheduling, while manual control can be performed directly through the ChrysoSmart application.
4) The system and application demonstrate stable data communication during field testing. Sensor data are transmitted and displayed in real time on the ChrysoSmart application, and control commands are executed by the actuators with fast and consistent responses, supporting effective remote monitoring and control.
5) The implementation of the system provides both technical and operational benefits for greenhouse management. From a technical perspective, the system integrates monitoring, automatic control, and manual control functions into a single IoT platform that is easy to implement. From an operational perspective, the system reduces reliance on manual monitoring, improves greenhouse environmental management efficiency, and supports stable growth conditions for chrysanthemum plants.

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