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Design and Development of an IoT-Based Prototype System for Monitoring the Care of Dendrobium Orchids

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ABSTRACT

The Dendrobium orchid (Dendrobium spp.) is widely appreciated for its beauty and durability in the horticultural industry. To ensure optimal growth, continuous monitoring of environmental conditions is essential. This research presents an Internet of Things (IoT)-based monitoring system that observes real-time temperature, humidity, and soil moisture levels around the orchid. The system utilizes a DHT22 sensor for measuring air temperature and humidity and a soil moisture sensor for detecting the moisture content of the growing medium. An ESP32 microcontroller processes the sensor data and transmits it to the Ubidots cloud platform for real-time visualization. Testing showed that the sensor system achieved an accuracy rate of 4%. Data consistency between the serial monitors and the cloud was maintained, except when network disruptions occurred. This system allows users to remotely monitor critical parameters necessary for orchid health, facilitating better decision-making and timely intervention, ultimately improving the effectiveness of orchid care and maintenance.

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1. INTRODUCTION

Orchid cultivation, particularly of the *Dendrobium* variety, is an important segment of the ornamental plant industry due to its aesthetic value and market demand. Achieving high-quality growth requires maintaining optimal environmental parameters, including soil moisture, temperature, humidity, and light intensity. Conventional cultivation methods often rely on manual observation and subjective decision-making, which can lead to inconsistent care and suboptimal growth outcomes, especially for inexperienced growers.

The emergence of Internet of Things (IoT) technology has enabled significant advancements in precision horticulture. By integrating sensors, actuators, and cloud-based data management, IoT systems allow for real-time environmental monitoring, data-driven decision-making, and automated actuation. Previous studies have demonstrated the application of IoT for plant care, including soil moisture control, microclimate monitoring, and irrigation scheduling. However, most existing systems focus on single-parameter monitoring or isolated automation, lacking a fully integrated approach that addresses multiple growth parameters simultaneously.

To address this gap, this research proposes an IoT-based integrated system for monitoring and automating the care of *Dendrobium* orchids. The system employs an ESP32 microcontroller connected to soil moisture, temperature–humidity, and light sensors, coupled with automated drip irrigation, misting, and ventilation controls. Sensor data are transmitted to the Ubidots cloud platform, enabling remote monitoring and control via web or mobile interfaces. The aim is to maintain consistent environmental conditions, reduce manual intervention, and improve overall plant health.

This study contributes to the advancement of smart agriculture by presenting a scalable, low-cost solution that combines multi-parameter monitoring with automated plant care. It also provides empirical evidence of the system's effectiveness through prototype testing under real cultivation conditions.

2. METHOD

This research followed an experimental method to design and implement an IoT-based monitoring and automation system for Dendrobium orchid care. The methodology includes literature review, problem identification, system requirements analysis, system design, implementation, testing, and data analysis. The research design was structured into hardware-software integration with real-time control and feedback.

The research procedure begins with a literature study to explore existing technologies related to environmental monitoring and plant care automation. Next, the specific problems in orchid cultivation were identified, including difficulties in maintaining humidity, temperature, and soil moisture. Based on this, the system requirements were studied and divided into functional and non-functional requirements. Hardware components such as ESP32, DHT22, soil moisture sensor (YL-69), fan module, mini water pump, mist nozzle, and ESP32 Shield were selected. Software requirements included Arduino IDE, Fritzing for wiring visualization, and Ubidots STEM for cloud data monitoring.

The system algorithm was written in C language using Arduino IDE. The following logic was applied:

1. Initialize Wi-Fi, sensors, and variables.
2. Read sensor values from DHT22 and YL-69.
3. Send data to Ubidots using MQTT protocol.
4. If soil moisture < 35%, activate mini water pump.
5. If temperature > 27°C, activate fan.
6. If air humidity < 60%, activate mist nozzle.
7. Repeat the cycle every 10 seconds.

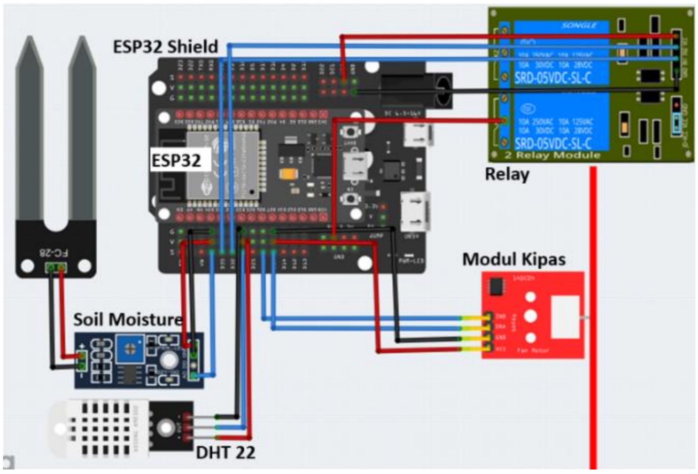

Figure 1. Wiring diagram of sensors and actuators connected to ESP32.

Figure 1 presents the wiring diagram illustrating the connections between the ESP32 microcontroller, sensors, and actuators in the system. The ESP32 serves as the central control unit, receiving data from the temperature–humidity sensor (DHT22) and the soil moisture sensor (YL-69), then activating the actuators according to the detected environmental conditions. The actuators include a DC fan for air circulation, a mini water pump for drip irrigation, and a mist nozzle for increasing air humidity.

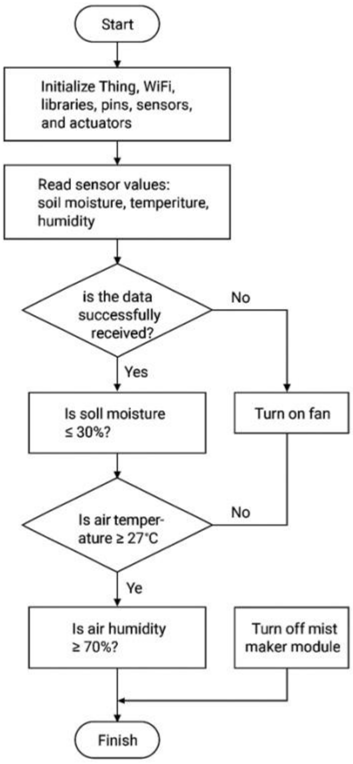

Figure 2. Flowchart Software

The flowchart illustrates the software design process for an automatic plant care and monitoring system. The process begins with the initialization of the system, which includes setting up the Thing, WiFi connection, libraries, pins, sensors, and actuators. Once initialized, the system reads environmental parameters such as soil moisture, air temperature, and air humidity. The collected data is then transmitted to the cloud database. If the data is not successfully received, the system repeats the transmission process until it is successfully stored in the database.

After data transmission, the system performs conditional checks to control the actuators. First, it checks the soil moisture level. If the soil moisture is less than or equal to 30%, the mini water pump is activated to water the plants; otherwise, the pump remains off. Next, the system evaluates the air temperature. If the air temperature is greater than or equal to 27°C, the fan is turned on to regulate the surrounding air; if not, the fan is turned off. Finally, the system checks the air humidity. If the humidity level is greater than or equal to 70%, the mist maker module is activated to maintain optimal humidity; otherwise, the mist maker is turned off. The process ends after all conditions are evaluated, and then the system loops back to continue monitoring and controlling the environment automatically.

3. RESULTS AND DISCUSSION

The developed IoT-based prototype for Dendrobium orchid maintenance was tested to evaluate its capability in autonomously controlling critical environmental parameters. The system architecture utilized an ESP32 microcontroller connected to various sensors and actuators, as illustrated in Figure 1. Each actuator was configured with predefined environmental trigger thresholds, and its performance was recorded under controlled experimental conditions.

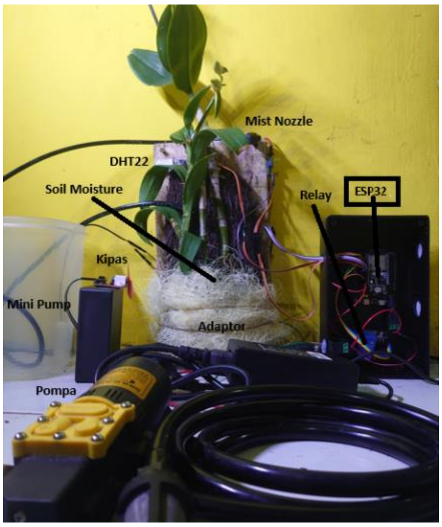

Figure 3. hardware implementation

The hardware implementation of the IoT-based orchid care system is shown in Figure X. The system is centered on an ESP32 microcontroller, which functions as the main control unit. The ESP32 is connected to a relay module that regulates the operation of several actuators. To acquire environmental parameters, two types of sensors are employed: the DHT22 sensor, which measures air temperature and humidity, and the soil moisture sensor, which monitors the water content of the planting medium.

The actuator components consist of a mini water pump and a mist nozzle, which work together to maintain soil and ambient humidity levels, and a fan that regulates air circulation and temperature around the orchid. The pump is supplied from a water reservoir, while the mist nozzle ensures fine water spray for maintaining the required humidity. The entire system receives power from an adapter, providing stable voltage for both the microcontroller and actuators.

Through the integration of sensors, actuators, and cloud connectivity via ESP32, the prototype enables automatic monitoring and regulation of environmental conditions, ensuring that the orchid receives optimal care without intensive manual intervention.

Table 1. Hardware performance summary.

Component	**Condition**	**Result**
Fan	Temp > 27°C	Temp reduced by 0.1°C in 64 sec
Mini Water Pump	Soil Moisture < 35%	Moisture increased to 88%
Mist Nozzle	Air Humidity < 60%	Humidity raised to 96%

Table 1 presents the summarized performance of each hardware component. The fan was set to activate when the ambient temperature exceeded 27 °C. Once triggered, the system recorded a gradual reduction of 0.1 °C within 64 seconds (Figure 2(a)). Although the cooling rate was moderate, it indicates stable thermal regulation without causing sudden temperature drops that could stress the orchids. In larger or more dynamic environments, upgrading the fan's airflow capacity or optimizing activation duration may yield faster cooling responses.

The mini water pump was programmed to operate when soil moisture dropped below 35%. Test results showed a significant increase in soil moisture from the trigger point to 88% after activation. This substantial improvement ensures that the orchid roots receive adequate hydration. However, in real greenhouse scenarios, the water delivery rate might need adjustment to prevent overwatering, which can cause root rot or fungal growth.

The mist nozzle was designed to activate when relative humidity fell below 60%. During testing, it successfully increased air humidity to 96% (Figure 2(b)), indicating a rapid and effective microclimate recovery. This capability is essential for Dendrobium orchids, which naturally thrive in humid tropical environments. Maintaining high humidity levels can reduce the risk of dehydration stress and improve overall plant health.

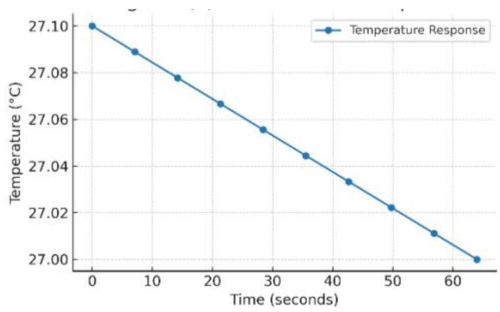

Figure 3(a). Fan Activation Response

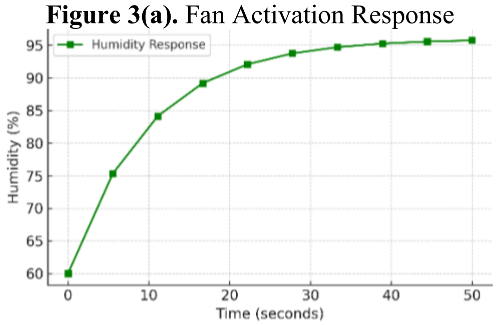

Figure 3(b). Mist Nozzle Activation Response

Figures 3(a) and 3(b) depict the system's response to changing environmental conditions. In Figure 3(a), the fan responds immediately after the temperature exceeds the threshold, showing a relatively steady rate of temperature reduction. Meanwhile, Figure 3(b) demonstrates the mist nozzle's rapid response in increasing air humidity, maintaining the humidity above the threshold to support optimal growth conditions for *Dendrobium* orchids.

Overall, these findings demonstrate that the proposed system effectively maintains temperature, soil moisture, and humidity within optimal ranges for Dendrobium orchid cultivation. The integration of real-time monitoring with automated actuation reduces the need for manual intervention, improves consistency in environmental control, and ensures that the plants remain in optimal growing conditions.

In future work, the system can be further developed and enhanced to broaden its applicability and efficiency. One possible direction is scaling up the prototype for larger greenhouse applications, allowing the system to manage multiple plants simultaneously under controlled environmental conditions. Additionally, the implementation of adaptive control algorithms can be considered to optimize both energy and water consumption, ensuring more sustainable operation. Another important improvement is the integration of data logging and storage features, which would enable long-term monitoring, growth analysis, and predictive maintenance, thereby supporting more precise and data-driven decision-making in plant care management.

4. CONCLUSION

The IoT-based monitoring system successfully integrates air temperature, air humidity, and soil moisture measurements into a single platform. Using an ESP32 with DHT22 and YL-69 sensors, the system provides accurate, real-time environmental data to the Ubidots Cloud for visualization and analysis. This solution reduces reliance on manual monitoring and enhances maintenance efficiency.

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