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PetalGrid: An AI–IoT Based Smart Garden Monitoring and Automated Irrigation System

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Abstract: ***Modern horticulture and botanical garden management require continuous monitoring of environmental conditions to maintain plant health and optimize resource usage. Traditional irrigation and monitoring methods rely heavily on manual observation, which often leads to inefficient water usage and delayed responses to environmental changes. This paper presents PetalGrid, an Artificial Intelligence (AI) and Internet of Things (IoT) based smart garden monitoring system designed to automate plant care using real-time environmental sensing and predictive analytics. The system integrates multiple sensors including soil moisture, temperature, humidity, and light sensors connected to a NodeMCU microcontroller. Sensor data is transmitted through Wi-Fi to a cloud-based dashboard where analytics and monitoring are performed. Machine learning techniques are utilized to analyze environmental patterns and predict irrigation requirements. Based on these predictions, the system can automatically control actuators such as water pumps and lighting systems. Experimental implementation demonstrates that PetalGrid enables efficient water management, reduces manual intervention, and improves plant health through intelligent automation. The system is scalable, secure, and suitable for applications ranging from small indoor gardens to large botanical environments.***

Keywords: IoT, Smart Irrigation, Artificial Intelligence, Environmental Monitoring, Smart Agriculture

I. INTRODUCTION

Environmental monitoring has become a critical requirement in modern agriculture and horticulture. Plants require precise conditions such as appropriate soil moisture, temperature, humidity, and light intensity to grow effectively. Maintaining these conditions manually is difficult and often inefficient, particularly in large gardens or botanical environments where multiple plant species exist with varying requirements.

Traditional irrigation systems typically operate on fixed schedules rather than responding dynamically to environmental changes. As a result, plants may receive either insufficient or excessive water, leading to reduced plant health and unnecessary water consumption. With increasing concerns about water scarcity and sustainable resource utilization, intelligent monitoring and automated irrigation systems have become increasingly important.

Recent advancements in the Internet of Things (IoT) and Artificial Intelligence (AI) enable the development of systems capable of collecting environmental data in real time and analyzing it intelligently to make automated decisions. IoT sensors can continuously measure environmental parameters, while AI algorithms can interpret these data streams to identify patterns, predict future conditions, and trigger appropriate control actions.

This research proposes **PetalGrid**, a smart garden monitoring and irrigation system that combines IoT sensing with AI-driven analytics to create an intelligent plant management ecosystem. The proposed system collects environmental data through distributed sensors, analyzes the information using predictive models, and automatically activates irrigation mechanisms when required. The system also provides a dashboard interface that allows users to monitor environmental conditions and receive alerts in real time.

The key contributions of this work include:

1) Development of an IoT-based environmental monitoring network for gardens.
2) Integration of AI-based predictive irrigation analytics.
3) Automated irrigation control using sensor feedback.
4) Real-time monitoring through a cloud dashboard.
5) A scalable architecture suitable for multiple garden environments.

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II. LITERATURE REVIEW

Several studies have explored the application of IoT technologies in agriculture and environmental monitoring. Smart irrigation systems based on soil moisture sensors have been proposed to improve water efficiency in agricultural environments. These systems typically collect soil moisture data and activate irrigation systems when moisture levels fall below predefined thresholds.

Research on IoT-based smart farming platforms demonstrates that sensor networks can significantly enhance crop monitoring and environmental management. Many existing systems focus primarily on data collection rather than predictive analytics or automation. Recent developments in AI have introduced predictive models capable of analyzing environmental trends and forecasting irrigation requirements. Machine learning algorithms such as regression models and decision trees can analyze historical sensor data to determine optimal watering schedules.

However, many current smart garden systems suffer from several limitations:

1) Lack of predictive intelligence
2) Limited automation capabilities
3) Poor scalability for larger environments
4) Weak data security mechanisms

PetalGrid addresses these challenges by integrating secure IoT communication, machine learning analytics, and automated environmental control mechanisms into a unified framework.

III. SYSTEM ARCHITECTURE AND METHODOLOGY

The PetalGrid system consists of three primary layers: the sensing layer, processing layer, and application layer.

A. Sensing Layer

The sensing layer includes environmental sensors placed within different plant zones. These sensors collect real-time environmental parameters such as:

1) Soil moisture
2) Temperature
3) Humidity
4) Light intensity

The sensors are connected to a NodeMCU microcontroller that acts as the central data acquisition unit.

B. Processing Layer

The processing layer is responsible for data transmission and analysis. Sensor data is transmitted via Wi-Fi using the NodeMCU module to a cloud-based platform where it is stored and processed. Machine learning algorithms analyze historical sensor readings to identify patterns and predict irrigation requirements.

The predictive model evaluates environmental conditions and determines whether irrigation should be triggered.

C. Application Layer

The application layer provides a user-friendly interface for system monitoring and control. Users can access real-time environmental data through a web dashboard or mobile interface. The dashboard displays sensor readings, environmental trends, and system alerts.

If abnormal environmental conditions are detected, notifications are sent to the user. Additionally, users can manually control irrigation systems through the interface if required.

IV. HARDWARE AND SOFTWARE IMPLEMENTATION

The prototype implementation of PetalGrid integrates both hardware and software components.

A. Hardware Components

The system utilizes the following hardware components:

1) NodeMCU (ESP8266) microcontroller
2) Soil Moisture Sensor
3) DHT11 Temperature and Humidity Sensor
4) LDR Light Sensor

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5) Relay Module
6) Water Pump
7) Breadboard and Jumper Wires

The overall architecture of the PetalGrid system is illustrated in Fig. 1, which shows the interaction between sensors, the NodeMCU controller, cloud storage, and the user dashboard.

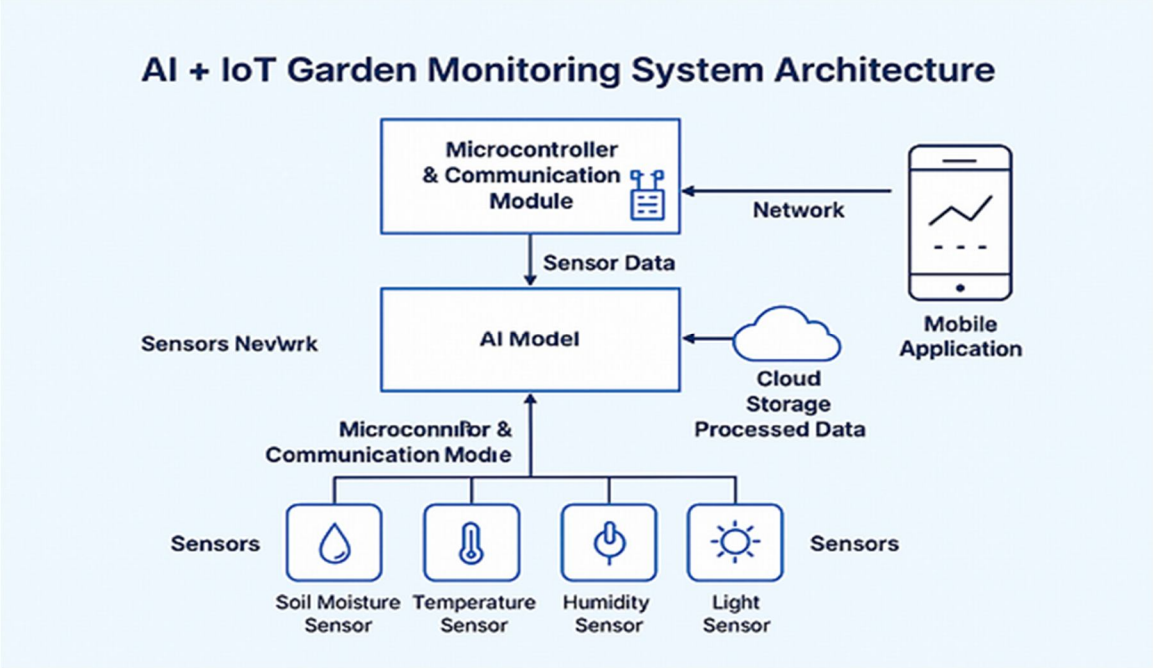
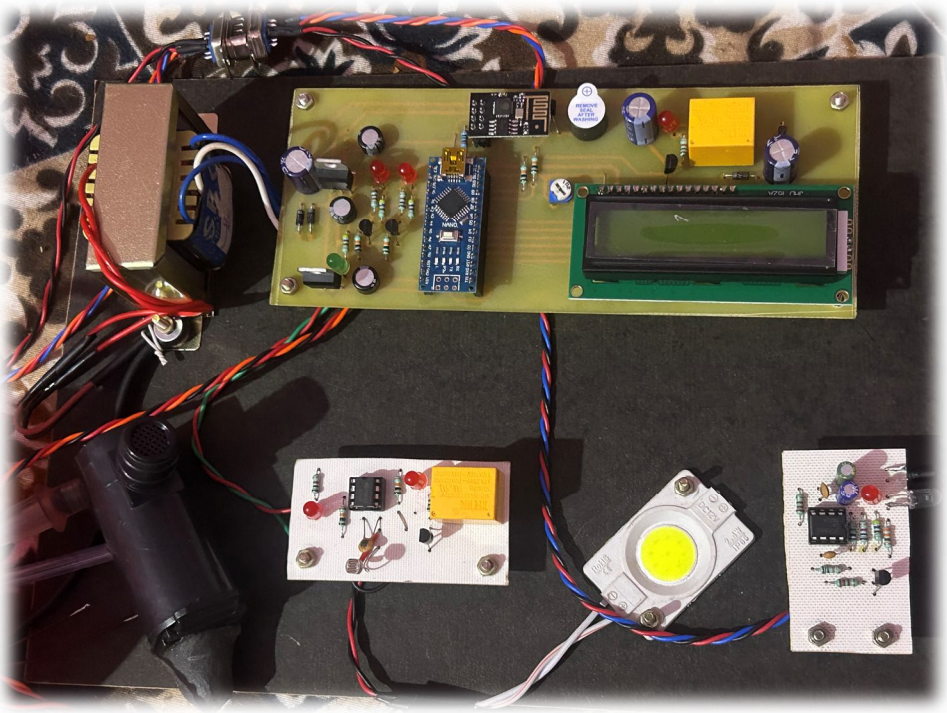


Fig. 1. PetalGrid System Architecture

The hardware setup of the proposed system is shown in Fig. 2.



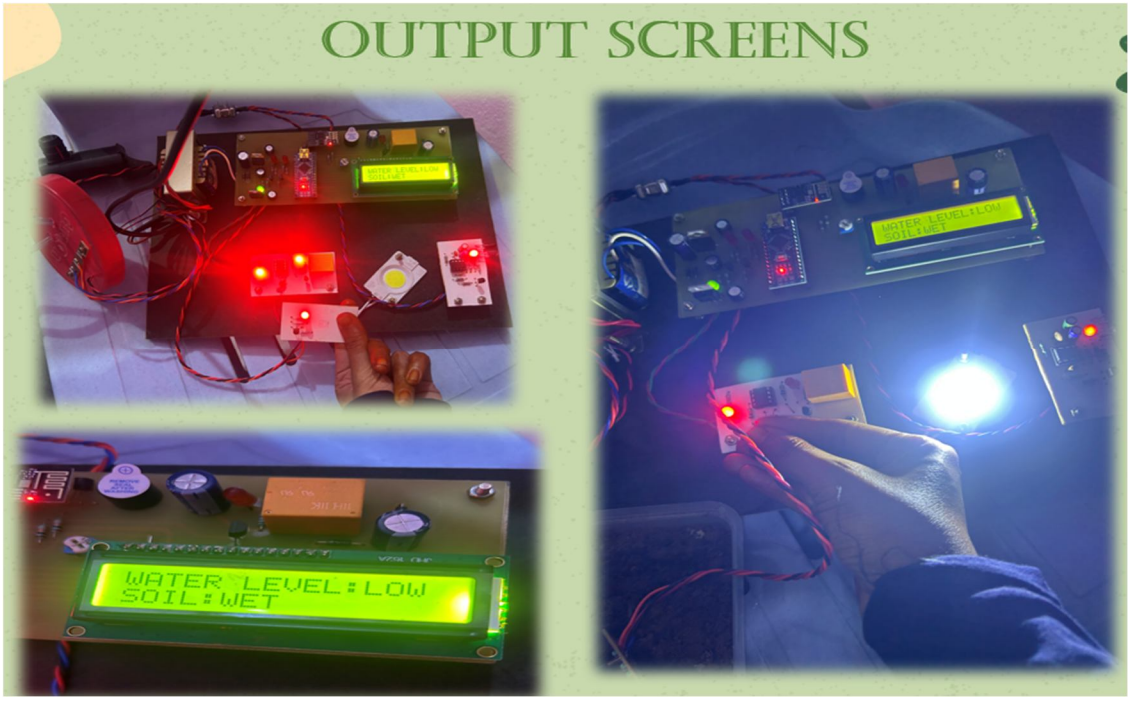


Fig. 2. Hardware Implementation Setup

The circuit diagram of the PetalGrid system illustrates the connection between the NodeMCU microcontroller and the environmental sensors including soil moisture sensor, DHT11 temperature and humidity sensor, and LDR light sensor. The relay module is connected to the NodeMCU to control the water pump for automated irrigation based on the sensor readings.

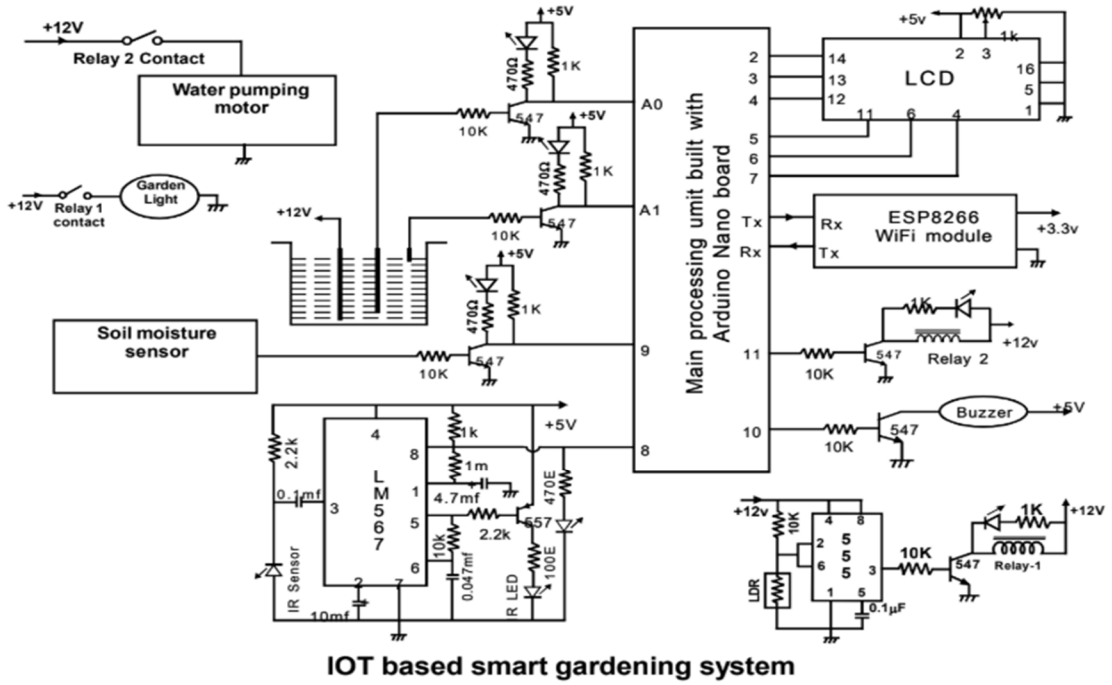


Fig. 3. Circuit Diagram of PetalGrid

The NodeMCU microcontroller reads sensor data and transmits the information to the cloud using its integrated Wi-Fi module. The relay module controls the water pump, enabling automated irrigation when required.

B. Software Components

The software implementation includes:

1) Arduino IDE for microcontroller programming
2) IoT cloud platform for data storage and visualization
3) Machine learning algorithms for predictive irrigation
4) Web dashboard for user interaction

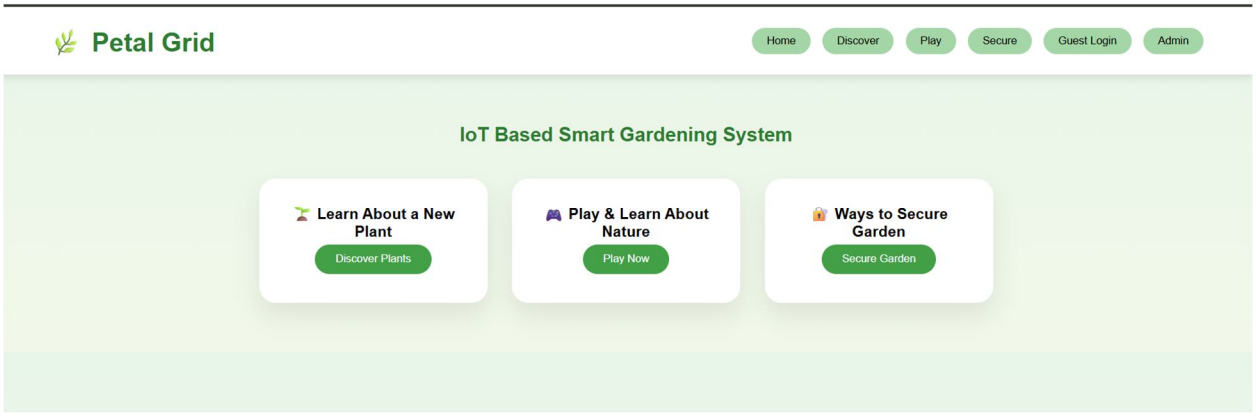


Fig. 4. Monitoring Dashboard Interface

The microcontroller program continuously collects sensor data and sends it to the cloud server. The system also checks moisture thresholds to determine whether irrigation should be activated.

V. RESULTS AND DISCUSSION

The PetalGrid prototype was tested in a controlled garden environment to evaluate its performance in monitoring environmental conditions and automating irrigation.

The system successfully collected real-time environmental data and displayed it on the dashboard interface. Soil moisture levels were continuously monitored, and irrigation was automatically triggered when moisture values dropped below the predefined threshold.

Experimental observations showed several advantages:

1) Continuous environmental monitoring
2) Automatic irrigation activation
3) Reduced water wastage
4) Faster response to environmental changes

Compared with manual irrigation methods, the system reduced unnecessary watering and improved efficiency. The predictive analytics module also demonstrated the ability to forecast irrigation needs based on historical sensor data patterns.

The results indicate that PetalGrid can effectively support sustainable garden management and intelligent horticulture practices.

The system achieved reliable sensor readings with minimal delay in data transmission and demonstrated efficient automated irrigation control during testing.

The experimental prototype validated the feasibility of integrating IoT sensing with intelligent automation for sustainable garden management.

VI. CONCLUSION

This paper presented PetalGrid, an AI and IoT based smart garden monitoring system designed to improve plant management through intelligent automation. The system integrates environmental sensors, wireless communication, cloud-based analytics, and automated irrigation mechanisms to maintain optimal plant conditions.

By combining real-time monitoring with predictive analytics, the system reduces water wastage and minimizes human intervention. The modular design allows the system to scale easily for larger garden environments or agricultural applications.

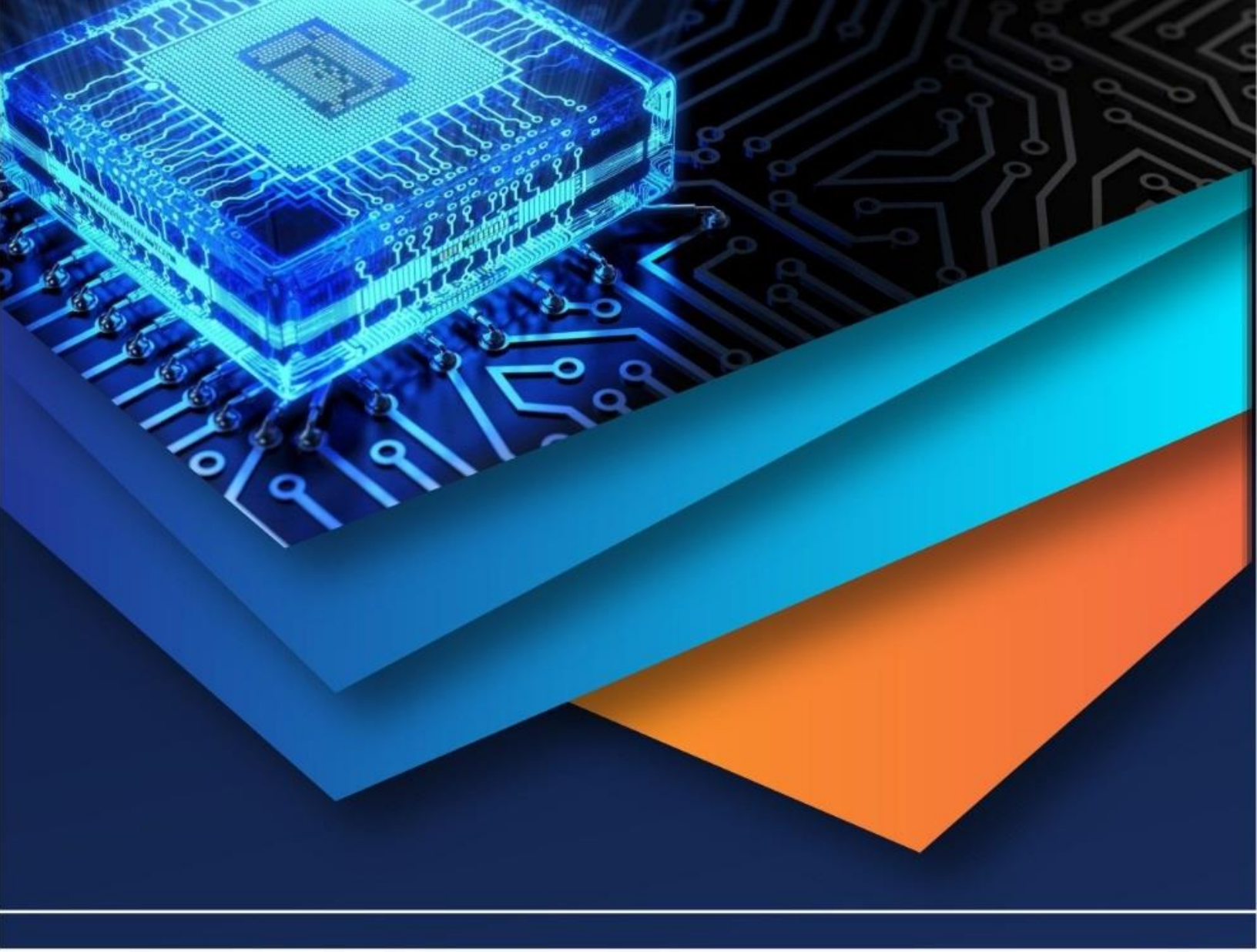
Future improvements may include integrating advanced machine learning models, mobile application support, and additional environmental sensors for more precise monitoring. PetalGrid demonstrates the potential of combining AI and IoT technologies to create sustainable and intelligent horticultural systems.

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