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Smart Mint Plant System for Air Temperature and Soil Moisture Control Using an IoT-Based Decision Tree Method

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Abstract
The rapid advancement of IoT technology has significantly contributed to the development of intelligent systems for modern agriculture. Mint plants, which thrive in specific environmental conditions (20–30°C temperature, 70–80% humidity, and full sunlight), require consistent monitoring and care to ensure optimal growth. Manual watering and environmental control can be labor-intensive and inefficient. To address this, an IoT-based smart system was developed to automate the control of air temperature and soil moisture for mint plants using a decision tree method. The system integrates sensors (DHT22 for temperature, soil moisture sensor), actuators (solenoid valve for irrigation, DC fan for cooling), and a microcontroller (ESP32) to process data and make real-time decisions. The system's performance was validated through component testing, showing high accuracy (average error of 0.96% for temperature and 0.9% for soil moisture) and effective actuator operation. The mint plants exhibited growth of 2 mm and produced 5 new shoots, demonstrating the system's efficacy. This research highlights the potential of IoT and decision tree algorithms in enhancing agricultural productivity and sustainability.

Keywords: Mint Plants, Decision Tree, Temperature, Soil Moisture

1. INTRODUCTION

The rapid advancement of technology, particularly in the field of the Internet of Things (IoT), has made a significant contribution to the development of intelligent systems supporting modern agriculture. The utilization of IoT enables real-time and integrated monitoring and control of agricultural environmental conditions, thereby improving the effectiveness and efficiency of crop management [1][2][3]. By employing microcontroller devices such as Arduino and ESP32 combined with DHT22 sensors and soil moisture sensors, IoT-based systems are capable of measuring critical parameters such as air temperature, humidity, and soil moisture. These parameters then serve as the basis for the automatic control of irrigation systems [4][5].

One of the main challenges in crop cultivation, including mint plants, is maintaining consistent environmental conditions that support optimal growth. Mint, for example, requires air humidity in the range of 70–80% and an ideal temperature of approximately 20–30°C [2]. The absence of appropriate monitoring and control systems often leads to unstable growing conditions, which negatively affect both the quality and productivity of the plants. This issue poses challenges not only for farmers but also for plant enthusiasts in maintaining sustainable plant care, particularly when environmental conditions are difficult to monitor manually [6][7].

A potential solution to this problem is the development of IoT-based monitoring and control systems integrated with artificial intelligence methods. Among the widely used algorithms is the decision tree, which has proven effective in processing sensor data to automatically generate decisions related to irrigation scheduling and temperature control [8][9][10]. The application of decision tree algorithms in IoT-based systems has achieved accuracy rates of up to 99.50% in optimizing irrigation schedules while simultaneously reducing water wastage by as much as 30% [9]. Furthermore, such systems can be equipped with remote monitoring features accessible via mobile or web applications, allowing users to observe plant conditions anytime and anywhere [11][12]. IoT-based implementations have also shown promising results in maintaining optimal growth conditions for various plants, including mint, tomatoes, and peppers, both in greenhouses and indoor environments [13][14].

The urgency of this research is further strengthened by evidence that IoT-based automated systems significantly enhance the efficiency of crop maintenance. Previous studies have demonstrated that similar technologies successfully optimized the growth of ornamental plants, strawberries, and rice through more precise soil moisture management [15][16][17]. Therefore, the development of a smart system specifically designed for mint cultivation is crucial not only for maintaining plant growth quality but also for improving productivity and minimizing repetitive manual intervention.

Based on this background, the aim of this study is to develop an IoT-based smart system capable of controlling air temperature and soil moisture for mint plants using the decision tree method. The proposed system is expected to maintain optimal growing conditions, provide convenient monitoring through digital devices, and enhance the efficiency of crop management. This research seeks to deliver a technological solution that addresses the challenges of mint cultivation in a modern, efficient, and sustainable manner.

2. METHOD

In this section, we will explain the method and system development of this research. This device utilizes IoT technology to facilitate remote monitoring of soil temperature and humidity for mint plants. The temperature and soil moisture levels will be monitored through the Blynk application system, where their values then function to automatically control the activation and deactivation of solenoid valves and fans. This is aimed at ensuring that the temperature experienced by the mint plants remains suitable, i.e., below 30°C, with soil humidity between 70 – 80%.

2.1 Literature Review

The literature review is conducted to identify fundamental knowledge related to the system to be designed, serving as the primary reference in the research. Some literature sources used include:

a. Basic principles and an overview of the soil temperature and humidity control system for mint plants using the IoT-based decision tree method.
b. Characteristics of circuits, electrical components, wireless communication, and sensors used in the research, including (a) ESP32, (b) DHT22 Sensor, (c) Soil Moisture Sensor, (d) Solenoid Valve, (e) Relay, (f) DC Fan.
c. The developed IoT system, specifically focusing on Wireless Communication.
d. Monitoring system for the temperature and soil humidity of mint plants.
e. Decision tree method.

2.2 Device Specification

The device specifications for the smart mint plant system consist of four parts: sensor, controller, actuator, and IoT-based monitoring system. In the sensor section, it reads the temperature and soil humidity of the mint plants. The sensors used are the DHT22 sensor for air temperature and Soil Moisture sensor for soil humidity. The parameter values obtained from the sensors are then used as variables in the controller to be processed using the decision tree method. The outputs from the determined variables are subsequently connected to the actuators.

The actuator functions as the controller to regulate the stability of soil temperature and humidity. The actuator consists of a DC fan to distribute cool air and a solenoid valve for automatic irrigation. Additionally, the monitoring system for soil temperature and humidity will be displayed through the Blynk application.

2.3 Mechanical Design

The mechanical design of this device consists of a project box, power supply, space for placing the DC fan, and a water reservoir. The project box measures 12 x 18 cm. For the mint plants, a solenoid valve and soil moisture sensor will be placed for automatic irrigation and detecting soil moisture levels. Meanwhile, the DHT22 temperature sensor will be positioned near the mint plants. This mechanical design can be seen in Figure 1 below.

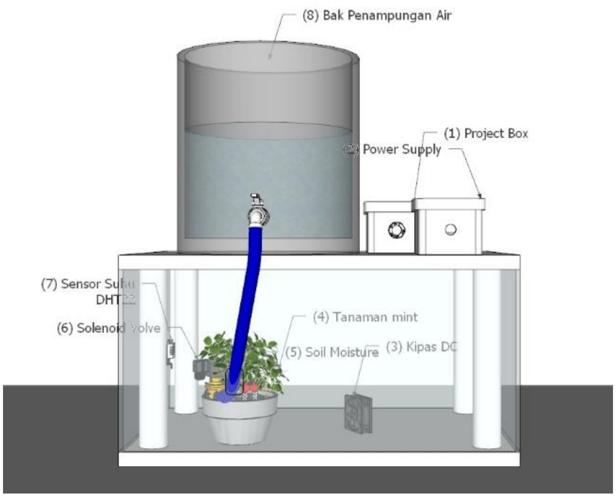

Figure 1. Mechanical Design

2.4 Block Diagram

In Figure 2, the block diagram of the system consists of 4 blocks: Input Block, Controller Block, Interface Block, and Output Block.

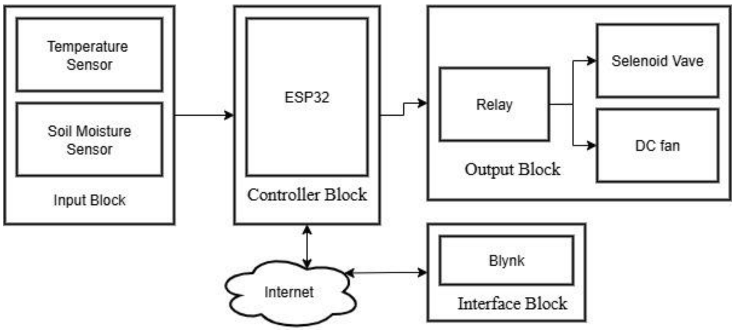

Figure 2. Block Diagram

The Input Block includes two types of sensors: temperature and soil moisture sensors. Both sensors read the temperature and soil moisture of the mint plants. The Controller Block uses ESP32 to process the temperature and soil moisture data using the decision tree method, which is then forwarded to the Output Block and subsequently to the Interface Block. In the Output Block, there is a relay that receives commands from the microcontroller, which are then passed on to the solenoid valve and DC fan. Lastly, there is the Interface Block, which is the Blynk application displaying the temperature and soil moisture values. This configuration allows for monitoring and control of the mint plant environment using IoT-based technology.

2.5 Hardware Design

The wiring diagram shows components connected and configured together. The ESP32 requires 5V power, with its pins connected to several components as follows: pin 4 is connected to the DHT22 data pin, pin 5 to relay input 1, pin 2 to relay input 2, and pin 35 to the soil moisture data pin.

The ESP32 pins connected to the DHT22 sensor are used to process air temperature data. Similarly, the ESP32 pins connected to the soil moisture sensor are used to process soil humidity data. The ESP32 pins connected to the relays control the on/off operation of the solenoid valve and the DC fan. Specifically, relay input 1 is connected to the solenoid valve, while relay input 2 is connected to the DC fan. The wiring diagram can be seen in Figure 3 below.

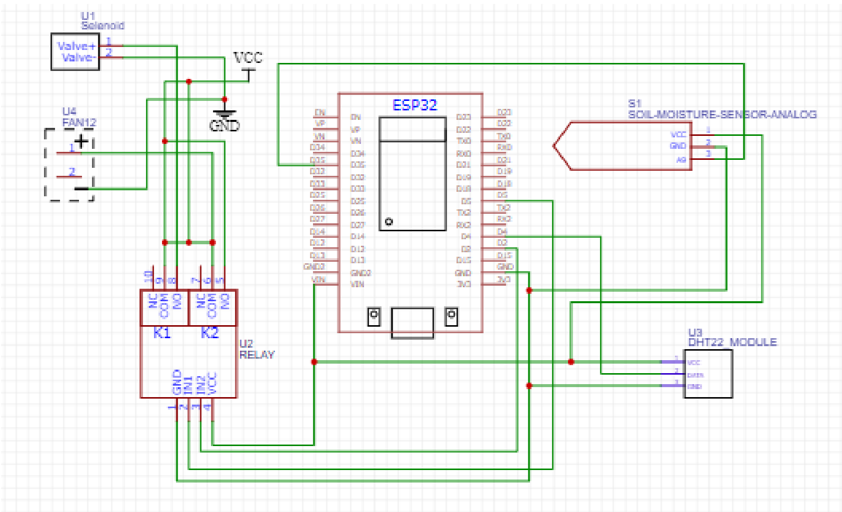

Figure 3. System Wiring Design

2.6 Decision Tree Method

In this method, the temperature and soil moisture detection functions as the root node representing the problem to be solved, which leads to several decisions or internal nodes. An internal node here is the soil moisture level, which then proceeds to a leaf node representing the final decision. In this case, the final decision determines the operation (on/off) of the fan and solenoid valve, as shown in Figure 4 below.

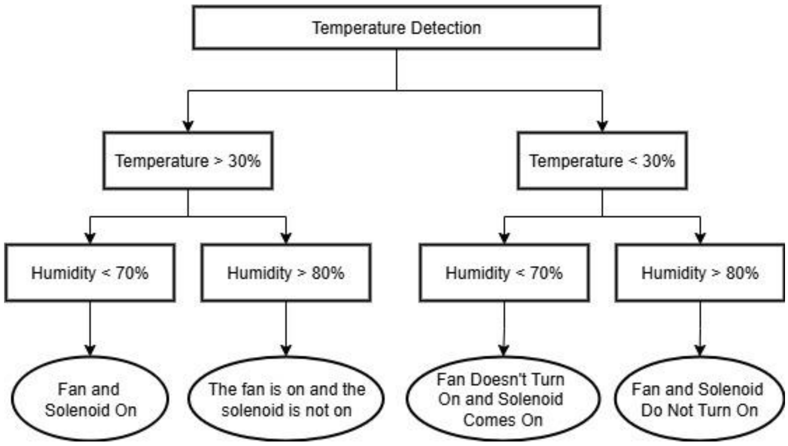

Figure 4. Decision Tree Method

2.7 Software Design

In Figure 5, it shows the flow diagram of the device. It begins with program initialization, followed by connecting to the internet. Once connected, the temperature and soil moisture sensors start detecting air temperature and soil humidity for the mint plants. Afterward, the temperature and soil moisture data values are processed by the microcontroller using the decision tree method.

The processed data is then sent to Blynk in real-time, and subsequently, the actuators adjust the temperature and soil humidity accordingly.

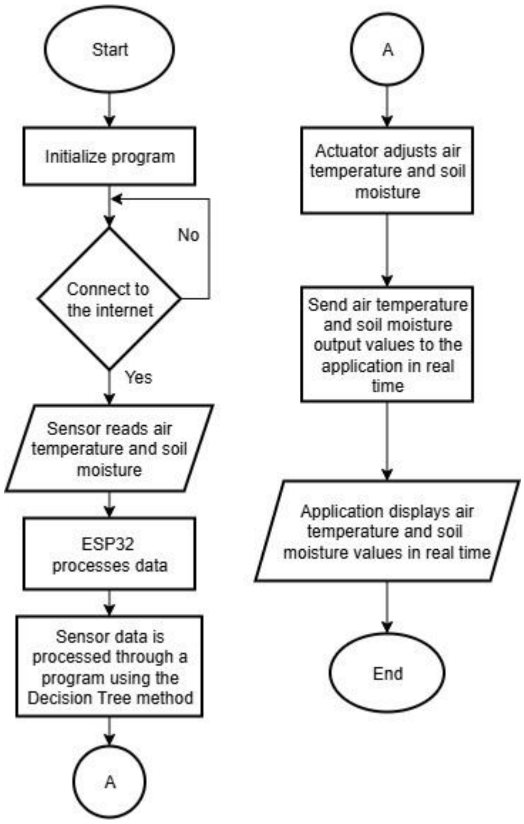

Figure 5. Software Design

2.8 Application Design

In the design of the Blynk application, the goal is to allow users to monitor real-time temperature and soil moisture levels. Users need to connect to Wi-Fi first to monitor the air temperature and soil moisture around the mint plants. The application interface includes temperature for air temperature around the mint plants, humidity for air humidity around the mint plants, and moisture for soil moisture in the mint plants. An illustration of this application can be seen in Figure 6 below.

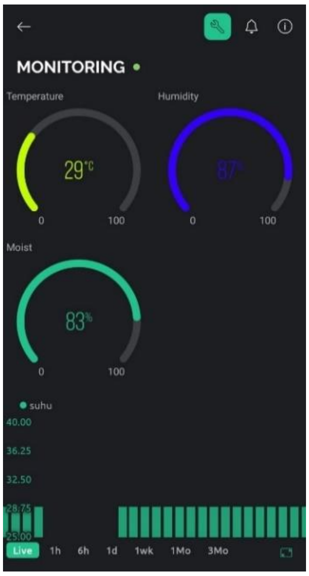

Figure 6. Application Design

3. RESULTS AND DISCUSSION

3.1 Temperature Sensor Testing

This testing is conducted to read the accuracy of the DHT22 sensor values against the ambient air temperature. Based on the testing in Table 1 below, values were obtained from comparing the DHT22 temperature sensor and the hygrometer. From these data, comparison will be made by calculating the error using the formula:

$$\%error = \frac{Temperature\ Sensor - Temperature\ of\ hygrometer}{Temperature\ of\ hygrometer}\ X\ 100 \qquad (1)$$

Based on the formula above, the average calculated error obtained is 0.96%.

Table 1. The Results of The Temperature Sensor Testing

Day-	Time (UTC+7)	DHT22	Hygrometer	Error *(%)*
1	06:00	26.20°C	26.90°C	2.60
	12:00	28.50°C	28.70°C	0.69
2	06:00	27.00°C	27.10°C	0.36
	12:00	29.00°C	29.20°C	0.68
3	06:00	27.00°C	27.30°C	1.09
	12:00	29.00°C	29.10°C	0.34
The Average				0.96%

3.2 Soil Moisture Sensor Testing

This testing is conducted to read the values from the soil moisture sensor regarding the soil moisture level in plants. In this test, the sensor will be placed on plants with varying soil moisture levels.

Based on the results from Table 2, the soil moisture sensor can accurately measure the soil moisture levels in plants. Dry soil moisture levels range from 0-40%, normal soil moisture ranges from 40-60%, and wet soil moisture ranges from 60-100%.

Table 2. The Results of The Soil Moisture Sensor Testing

Dry Soil Mass (Kg)	Water Mass (Kg)	Moisture Calculation Results (ASM)	Soil Moisture Sensor
0.55	0.07	12.70	36.00%
0.55	0.14	25.40	39.00%
0.55	0.21	38.18	42.00%
0.55	0.28	50.90	44.00%
0.55	0.35	63.60	47.00%
0.55	0.42	76.30	49.00%
The Average		44.40	45.30%

The standard or reference for measuring soil moisture is using the American Standard Method (ASM). This method compares the mass of water to the mass of soil grains (dry soil mass). as indicated by the following equation:

$$\%Soil\ Moisture = \frac{Water\ Mass}{Moisture\ Mass}\ X\ 100\% \qquad (2)$$

The mass of soil grains is obtained by weighing the dry soil. while the mass of water is obtained by comparing the mass of soil grains that have been watered to the mass of dry soil. In the above test. the average difference between the ASM calculations and the sensor readings is minimal. only 0.9%

3.3 DC Fan Testing

This testing is conducted to determine the on-off operation of the DC fan according to the programmed settings. The testing will use temperature parameters < 30 and > 30.

Based on the test results in Table 3 below. the DC fan operates according to the programmed settings. The DC fan will turn on if the temperature is > 30. and it will turn off if the temperature is < 30. In this testing phase. it can be confirmed that the DC fan functions properly.

Table 3. The Results of The DC Fan Testing

No	Temperature	DC Fan
1	26°C	Off
2	28°C	Off
3	29°C	Off
4	30°C	On
5	31°C	On
6	32°C	On

3.4 Solenoid Valve Testing

This testing is conducted to determine the opening and closing of the solenoid valve according to the programmed settings. The testing will use humidity parameters < 70% and > 80%.

Based on the test results in Table 4 below. the solenoid operates according to the programmed settings. The solenoid will activate if the soil moisture level in the plants is < 70%. and it will deactivate if the soil moisture level in the plants is > 80%. In this testing phase. it can be confirmed that the solenoid is capable of opening and closing the valve effectively. ensuring that the water output meets the plants' requirements.

Table 4. The Results of The Solenoid Valve Testing

Number of Plants	Soil Moisture	Solenoid Valve
Plant 1	58%	High / open
Plant 2	62%	High / open
Plant 3	66%	High / open
Plant 4	78%	High / open
Plant 5	82%	Low / closed
Plant 6	84%	Low / closed

3.5 Overall System Testing

This testing is conducted to understand how the device operates and assess the success rate of the device according to the specified specifications. From Table 5. it can be concluded that mint plants with this automatic watering system can grow up to 2mm and produce shoots periodically up to the fifth shoot. Therefore. it can be concluded that this device operates effectively.

Table 5. The Results of The Overall System Testing

Day-	Temperature	Moisture	Length of Plants	Conditions of The Plants
1	29°C	64%	17.8 cm	No Changes Yet
2	29°C	62%	17.8 cm	No Changes Yet
3	29°C	84%	18.0 cm	The first shoot is growing
4	29°C	83%	18.0 cm	The second and third shoots are growing
5	27°C	76%	18.0 cm	The fourth shoot is growing
6	27°C	78%	18.0 cm	The fifth shoot is growing

4. CONCLUSION

The study successfully developed an IoT-based smart system for controlling air temperature and soil moisture in mint plant cultivation using a decision tree method. Key findings include:

a. Sensor Accuracy: The DHT22 temperature sensor and soil moisture sensor demonstrated high precision. with average errors of 0.96% and 0.9%. respectively. ensuring reliable environmental monitoring.
b. Actuator Performance: The DC fan and solenoid valve operated effectively based on decision tree logic. maintaining optimal conditions (temperature ≤30°C. soil moisture 70–80%).
c. Plant Growth: The system supported mint plant growth (2 mm increase in height) and stimulated the production of 5 new shoots. validating its practical benefits.
d. Efficiency: The integration of IoT and decision tree algorithms reduced manual intervention while optimizing resource use. aligning with sustainable agriculture goals.

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