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SMART WATER PUMP DESIGN USING DECISION TREE FOR IOT-BASED AUTOMATIC FRUIT PLANT IRRIGATION

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Abstract

The continuous growth of the population increases the demand for food while agricultural land becomes more limited. One solution is the tabulampot technique, which involves growing fruit in pots. Irrigating tabulampot plants is essential to maintain fruit quality, but manual irrigation is time-consuming and labor-intensive, requiring an automation system. This study aims to design an intelligent water pump system based on the Internet of Things (IoT) using the Decision Tree algorithm to monitor and irrigate these plants. The soil moisture sensor is connected to the NodeMCU ESP8266 as the data processor, which is linked to the internet. The system automatically irrigates the plants based on soil moisture conditions and a set time, with real-time monitoring and control through the Blynk application on a smartphone. The results of this study show that the Decision Tree algorithm successfully processes soil moisture data, classifying the soil as "dry" or "wet." The system activates a relay to turn on the water pump when dry soil is detected. IoT enables the system to function automatically and be controlled remotely, optimizing plant care, reducing the farmers' workload, and improving water usage efficiency.

Keywords: *Potted Fruit Plants; Decision Tree, Soil Moisture, Internet of Things, Smart Irrigation System.*

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1. INTRODUCTION

The continuous growth of the population increases every year [1], demanding sufficient food supply [2]. Additionally, it causes home garden areas to become limited, making it difficult for communities to grow fruit plants [3]. One new trend in planting is the technique of growing fruit in pots (tabulampot) [4]. Tabulampot is a solution to the problem of limited land [5]. One maintenance stage for tabulampot is irrigation. The application of deficit irrigation in fruit production is a strategy to manage fruit quality [6]. The water needs of tabulampot must be carefully monitored due to the limited volume of the growing medium, as roots can quickly become stressed if water is insufficient. Water must always be monitored, especially during the dry season or if the plants have a canopy [7]. Water loss causes wilting, shrinkage, browning, loss of fruit texture, taste, and weight, which can affect marketability and accelerate aging [8]. Irrigation should ideally be done daily [9], while during the dry season, it should be done every two to three days according to soil moisture. Avoid overwatering, as prolonged sogginess can lead to root rot and yellowing leaves [10]. This process can consume time and energy since farmers must constantly check soil moisture and water daily [11].

Research and development on smart farming focusing on irrigation processes have been widely conducted. For instance, a study by Anwar Fu'adi and Agus Priangono in 2020 titled "Automatic Irrigation System for Potted Fruit Plants Based on Arduino" simulated an automatic irrigation system based on decision-making, resulting in a functioning prototype according to predetermined decisions. The prototype was developed using four decisions within the SDLC [12]. Another study by Tri Watiningsih, Yohana Nursuwening, and Reni Sulistyowati AM successfully created a timer controller for irrigation in tabulampot using a scheduling method. The automatic irrigation based on plant needs proved to be more effective and efficient compared to other irrigation methods [13]. Furthermore, research conducted by Effendy Candra Sasmoro and Devi Yunita in 2023 developed an Automatic Irrigation System for Potted Fruit Plants based on the Internet of Things, utilizing Wemos D1, soil moisture sensors, relay modules, and water pumps [14].

The novelty of this research, which distinguishes it from previous studies, is the application of the Decision Tree algorithm to determine the decisions made by the system based on the moisture values read by the sensor, thus allowing for more accurate decision-making. The system will irrigate based on two conditions: predetermined times and soil moisture conditions, maximizing irrigation efficiency. The system will be controlled via smartphone, enabling mobile access anytime and anywhere. This system leverages Internet of Things technology, ensuring control is unlimited as long as the system and user are connected to the internet.

The main reason for conducting this research is that irrigation and monitoring of tabulampot are still done manually by farmers, whereas proper irrigation is crucial; otherwise, it leads to wasted time and effort.

Based on the explanation above, the goal of this research is to design and build a smart water pump system using the Decision Tree algorithm as a monitoring and automatic irrigation tool for potted fruit plants based on Internet of Things technology.

2. RESEARCH METHODS

2.1 Research Stages

This study was conducted through five main stages to design a Smart Water Pump based on the Internet of Things (IoT) using the Decision Tree algorithm. The first stage is problem identification, which focuses on the application of technology to enhance the efficiency of automatic irrigation for tabulampot plants. Next, a literature review is conducted to understand the concepts of Wireless Sensor Networks (WSN), automatic irrigation systems, the Decision Tree algorithm, and tabulampot cultivation methods. After that, data collection is carried out related to the irrigation needs of plants, environmental characteristics, and the parameters used in decision-making based on sensors. In the system design and development stage, sensor network design, implementation of the Decision Tree algorithm, user interface (UI) development, and system integration with IoT technology are performed. The final stage is result evaluation, where the system is tested to measure the accuracy of sensors, the effectiveness of the algorithm in determining irrigation needs, and the overall system performance in supporting the automation of tabulampot plant irrigation. With these stages, it is hoped that the developed Smart Water Pump system will function optimally in monitoring and automatic irrigation based on IoT. The research stages are shown in Figure 1.

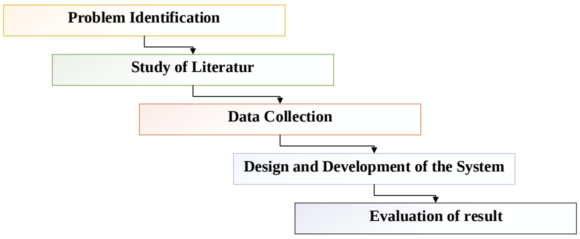


Figure 1. Research Stages

2.2 System Diagram

The system diagram for the system to be created can be seen in Figure 2. This diagram illustrates how each potted fruit plant (tabulampot) system consists of a soil moisture sensor, relay, and water pump connected to the NodeMCU ESP8266. Each tabulampot system sends data to Blynk Cloud via the internet, allowing the data to be accessed in real-time through a monitoring application available on smartphones.

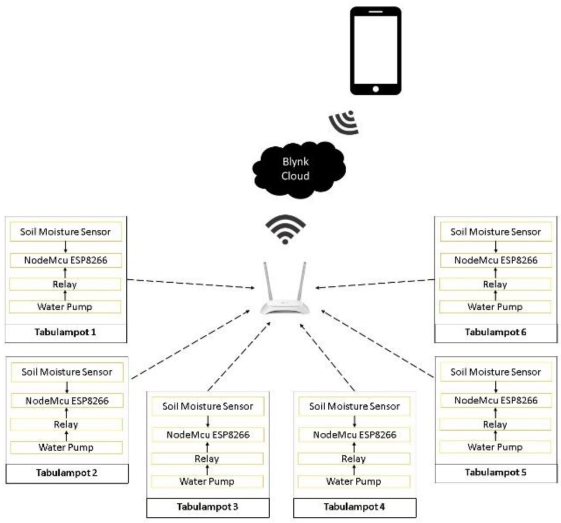


Figure 2. System Diagram

2.3 Design of the Decision Tree Algorithm in the System

A decision tree is a type of tree structure where testing attributes are represented by each node, test outcomes by each branch, and specific class groups by each leaf node [15]. The decision tree algorithm is used to determine the decisions made by the system based on the moisture values provided by the sensor [16]. The design results of the algorithm to be applied to the system can be seen in Figure 3.

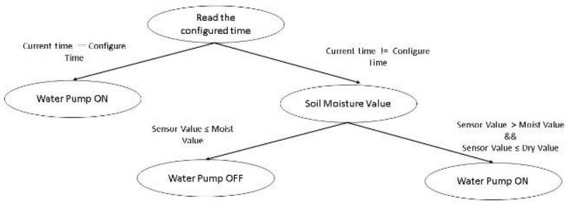


Figure 3. Design of the Decision Tree Algorithm

The application of the decision tree algorithm is used to determine the irrigation decisions for potted fruit plants based on the scheduled time and soil moisture values. Initially, the system checks the time set in the monitoring application. If the scheduled time matches the current time, the system will perform irrigation. If not, the system will proceed to check the soil moisture value. If the detected moisture value is below the predefined moist soil level, the system will not irrigate. However, if the detected sensor value is above the specified moist and dry soil levels, the system will carry out irrigation.

3. RESULTS AND DISCUSSION

This research has successfully developed a smart water pump system using a decision tree algorithm as a monitoring and automatic watering tool for potted plants based on the Internet of Things.

3.1 Design of Hardware

The results of the hardware design for the system can be seen in Figure 4.

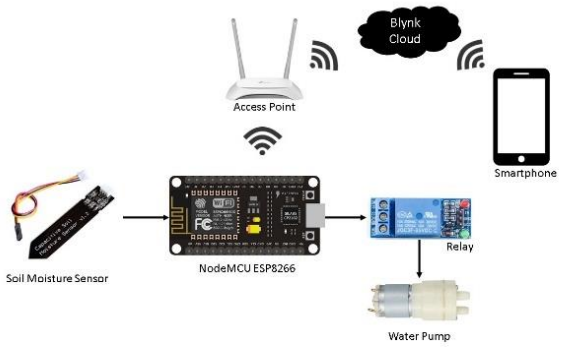


Figure 4. Design of Hardware

3.2 Design of Software

The results of the software design to be implemented in the system can be seen in Figure 5.

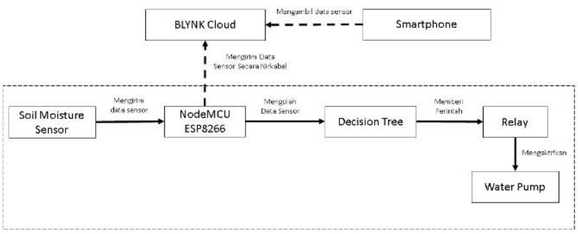


Figure 5. Software Design of the System

3.3 System Implementation

System implementation is a phase of system development carried out in stages to form a cohesive system. This process begins with design and culminates in the creation of a smart water pump system that functions as an automatic irrigation and monitoring tool for potted fruit plants (tabulampot) using Internet of Things technology, the decision tree algorithm, and a monitoring application developed on the Blynk platform.

3.3.1 System Hardware

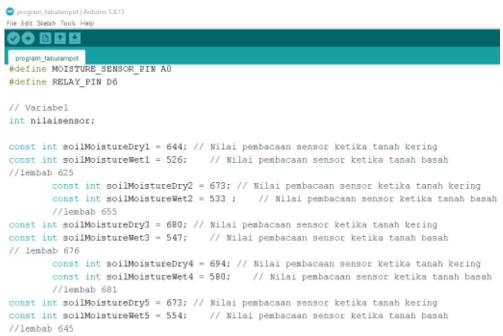
The hardware used in the creation of the Sensor Node circuit includes the Soil Moisture Sensor V.2.0, which functions to detect soil moisture; the NodeMCU ESP8266, which processes the data read by the sensor; a relay that activates the water pump; and the water pump itself, which delivers water to the potted fruit plants (tabulampot). The system hardware can be seen in Figure 6.

Figure 6. System Hardware

3.3.2 Results of Software Development

System Software

The implementation of the system software aims to test whether each hardware component functions as expected. This system software is developed using the Arduino IDE by writing lines of code, which are then uploaded to the NodeMCU ESP8266. The sample code can be seen in Figure 7.




```
#define MOISTURE_SENSOR_PIN A0
#define RELAY_PIN D6

// Variabel
int nilaisensor;

const int soilMoistureDry1 = 644; // Nilai pembacaan sensor ketika tanah kering
const int soilMoistureWet1 = 526;    // Nilai pembacaan sensor ketika tanah basah
//lembab 625
        const int soilMoistureDry2 = 673; // Nilai pembacaan sensor ketika tanah kering
        const int soilMoistureWet2 = 533 ;    // Nilai pembacaan sensor ketika tanah basah
        //lembab 655
const int soilMoistureDry3 = 680; // Nilai pembacaan sensor ketika tanah kering
const int soilMoistureWet3 = 547;    // Nilai pembacaan sensor ketika tanah basah
// lembab 676
        const int soilMoistureDry4 = 694; // Nilai pembacaan sensor ketika tanah kering
        const int soilMoistureWet4 = 580;    // Nilai pembacaan sensor ketika tanah basah
        //lembab 681
const int soilMoistureDry5 = 673; // Nilai pembacaan sensor ketika tanah kering
const int soilMoistureWet5 = 554;    // Nilai pembacaan sensor ketika tanah basah
//lembab 645
```

Figure 7. System Software

Monitoring Software

The testing of the monitoring software aims to ensure that the developed software can effectively display soil moisture sensor data. This software is created using the Blynk platform, as shown in Figure 8.

Figure 8. Monitoring Software

The values displayed in Figure 7 represent the soil moisture sensor readings converted into percentage form.

3.3.3 Installation of Hardware

The fully functional system will be installed on each potted fruit plant (tabulampot) to monitor and irrigate the plants automatically, as shown in Figure 9.


Figure 9. Installation of the System on Potted Fruit Plants

3.4 Testing Results of Each Component

Overall, the system operates by monitoring soil moisture and automatically irrigating the potted fruit plant media using Internet of Things (IoT) technology. The system consists of a soil moisture sensor that detects the moisture level of the potted fruit plants, which is then sent to the NodeMCU ESP8266 for processing using the decision tree algorithm to determine whether the planting media is dry or moist. If any planting media is detected as dry, the NodeMCU ESP8266 activates a relay to turn on the water pump for irrigation. Additionally, the NodeMCU ESP8266 also sends real-time data from the sensor to Blynk Cloud, which can be accessed through the monitoring application.

3.4.1 Sensor Testing Results

Sensor testing was conducted to determine the values from the soil moisture sensor and to establish the categories of dry and moist by comparing the moisture sensor readings with those from previously existing sensors. The data obtained from the sensor will then be processed by the NodeMCU ESP8266 using the decision tree algorithm. This testing was performed on all six devices that will be installed on each potted fruit plant (tabulampot). The testing can be seen in Figure 10.


Figure 10. Testing and measuring the soil moisture sensor readings for dry and moist soil.

The results of the sensor node testing can be seen in Table 1.

Table 1. Sensor Testing Results

Device	Sensor Value in Soil Condition	
	Dry	Moist
1	644	625
2	673	655
3	680	676
4	694	681
5	673	645
6	669	649

After obtaining the sensor values, the next step is to input these values into the program code, which will be processed automatically by the system using the decision tree algorithm to determine the maximum and minimum values for the wet and moist categories.

3.4.2 Implementation of the Decision Tree Based on Sensor Testing Results

After the sensor testing is performed by reading the sensor values in the soil, the next step is to determine the condition of the Relay and Water Pump based on the rules in the Decision Tree.

Data Grouping Based on Soil Condition

From the obtained data, the soil condition is divided into two main categories based on the sensor values. This data can be seen in Table 2.

Table 2. Soil Category Grouping

Soil Condition	Relay Condition	Water Pump
Dry	ON	ON
Moist	OFF	OFF

Determining the Threshold

The threshold can be calculated using the mean (average) sensor values between dry and wet conditions. Each sensor will have its threshold value determined so that it can later be incorporated into the program code. Below is an example of threshold calculation where the sensor data being calculated is from device 1.

$$Treshold = \frac{(\text{Mean Dry} + \text{Mean Humid})}{2}$$
$$Treshold = \frac{(644\ +\ 625)}{2}$$
$$Treshold = \frac{1269}{2}$$
$$Treshold = 634.5$$

Decision Rules Based on the Decision Tree

The decision structure can be visualized in the form of a simple decision tree in Figure 11.

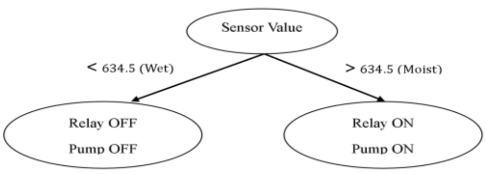


Figure 11. Decision Tree

3.4.3 Overall System Testing Results

The overall system testing aims to evaluate the system's performance in detecting soil moisture values, irrigation, and sending data to the Blynk cloud. The testing was conducted under two conditions: dry soil and wet soil. The test results can be seen in Table 3 and Table 4.

Table 3. Results of System Testing on Dry Soil

Device	Sensor Value	Relay Condition	Water Pump Conditio	Blynk Status
1	644	ON	ON	Success
2	673	ON	ON	Success
3	680	ON	ON	Success
4	694	ON	ON	Success
5	673	ON	ON	Success
6	669	ON	ON	Success

Table 4. Results of System Testing on Moist Soil

Device	Sensor Value	Relay Condition	Water Pump Conditio	Blynk Status
1	625	OFF	OFF	Success
2	655	OFF	OFF	Success
3	676	OFF	OFF	Success
4	681	OFF	OFF	Success
5	645	OFF	OFF	Success
6	649	OFF	OFF	Success

3.4.4 Hasil Pengujian RTC (Real Time Clock)

The RTC used is the one provided by the NodeMCU ESP8266, utilizing the server time from the NodeMCU itself. This RTC value will be compared with the scheduled irrigation time set in the monitoring application. If the time on the RTC matches the scheduled time in the monitoring application, the system will initiate irrigation. This testing was conducted by observing the alignment between the RTC time and the time set in the monitoring application. The results of the testing can be seen in Table 5.

Table 5. RTC Testing Results

RTC Time	Time Set in the Application	Watering
10.00	10.00	Watering
09.00	10.00	Not Watering

4. CONCLUSION

After undergoing a series of research phases, including the design, development, and testing of a monitoring and automatic watering system for potted plants using a decision tree algorithm based on the Internet of Things, it can be concluded that this research has produced a system capable of automatically watering and monitoring potted plants. The study involves six potted plant locations, each with devices that read and transmit soil moisture data to Blynk Cloud in real-time using Internet of Things technology.

The test results indicate that the six systems developed successfully read soil moisture data in real-time and transmit this information to Blynk Cloud. Furthermore, the algorithm implemented in this system, the decision tree, effectively processes the readings from the soil moisture sensors, allowing the system to determine whether the plants need watering. The monitoring application developed is capable of displaying soil moisture data as a percentage (%), enabling farmers to know the moisture levels of the six potted plants.

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