

IoT-Based Soil Moisture Monitoring and Drip Irrigation System for Chili Plants Using NodeMCU and Blynk

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Abstract

Soil moisture is an important factor affecting the growth and productivity of chili plants. Manual irrigation often results in inefficient water usage because it does not consider the actual soil moisture conditions. This study aims to design and develop an Internet of Things (IoT)-based drip irrigation system using the NodeMCU ESP8266 to monitor soil moisture and perform automatic irrigation through the Blynk application. The system utilizes four YL-69 Soil Moisture sensors, a DHT22 temperature sensor, a relay module, a DC water pump, an I2C LCD, and the Median Filter method to produce more stable soil moisture data. The water pump is automatically activated when the soil moisture level falls below 60% and is turned off when the moisture level reaches or exceeds 60%. The testing results show that the system is capable of distinguishing soil moisture levels under three different soil conditions. The Median Filter values obtained were 35,5% for dry soil, 62% for moist soil, and 87% for wet soil. The system successfully activated the water pump automatically when the soil moisture level was below the predefined threshold and stopped irrigation when the moisture level reached the optimal condition. In addition, soil moisture and air temperature data could be monitored in real time through the I2C LCD and the Blynk application.

Keywords: Internet of Things (IoT), Drip Irrigation, YL-69 Soil Moisture Sensor, Median Filter, Blynk.

1. Introduction

Chili pepper (*Capsicum annum L.*) is one of the most important horticultural commodities in Indonesia. The growth and productivity of chili plants are strongly influenced by soil moisture conditions. Inappropriate irrigation management can reduce plant growth and crop yield. Therefore, maintaining optimal soil moisture is essential to support sustainable chili cultivation [1], [2]. Conventional irrigation is generally performed manually without considering actual soil moisture conditions, resulting in inefficient water usage. Drip irrigation is considered an effective method because water is delivered directly to the plant root zone, thereby reducing water loss and increasing irrigation efficiency [3], [4]. The development of Internet of Things (IoT) technology has enabled irrigation systems to operate automatically through sensor-based monitoring and internet communication [5], [6].

Several studies have implemented IoT-based irrigation systems using soil moisture sensors to improve irrigation management. However, fluctuations in sensor readings may affect irrigation accuracy. Therefore, a filtering method is required to obtain more stable measurement data before controlling the irrigation process [7], [8]. This study proposes an IoT-based drip irrigation system for chili plants using NodeMCU ESP8266, four YL-69 soil moisture sensors, a DHT22 sensor, and the Blynk application for real-time monitoring. The Median Filter method is applied to reduce sensor noise and improve data stability. The system automatically activates the water pump when soil moisture is below 60% and stops irrigation when soil moisture reaches or exceeds 60%. Experimental results show that the system successfully distinguishes dry, moist, and wet soil conditions with median values of 33.5%, 63.5%, and 84.5%, respectively, demonstrating the effectiveness of the proposed system in supporting efficient irrigation management [8], [9], [10].

2. Research and Methods

This study proposes an Internet of Things (IoT)-based drip irrigation system for monitoring soil moisture and automatically controlling irrigation for chili plants. The research method consists of system design, implementation, testing, and performance evaluation.

2.1. Research Methodology

This research was conducted to develop an Internet of Things (IoT)-based drip irrigation system for chili plants. The research methodology consists of problem identification, literature review, system analysis, hardware and software design, implementation, testing, and evaluation.

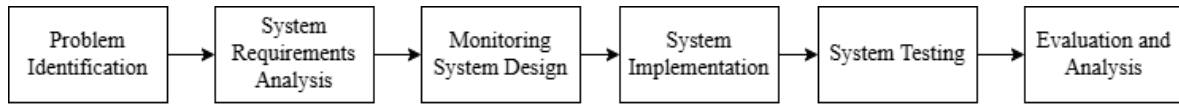


Fig. 1: Research Methodology Structure

2.2 Median Filter Analysis

Soil moisture measurements obtained from analog sensors are often influenced by sensor noise, environmental conditions, and differences in soil characteristics. These factors may produce unstable readings that can affect the accuracy of automatic irrigation decisions. Therefore, this study applies the **Median Filtering** algorithm to improve the stability of soil moisture measurements before they are processed by the NodeMCU ESP8266. The proposed system utilizes four YL-69 soil moisture sensors installed at different locations around the chili plants. The sensor readings are collected simultaneously and sorted in ascending order. Since the system uses four sensor values (an even number of observations), the median value is calculated as the average of the two middle values. This median value is then used as the representative soil moisture value for controlling the irrigation system.

The median value is calculated using Equation (1).

$$Median = \frac{X_{\frac{n}{2}} + X_{(\frac{n}{2})+1}}{2}$$

Where:

X = Sorted soil moisture sensor values

n = Total number of soil moisture sensor readings

Median = Representative soil moisture value used for irrigation control

The calculated median value is compared with predefined soil moisture thresholds to determine the irrigation status. When the median value is below **60%**, the relay activates the DC water pump to start the drip irrigation process. Conversely, when the median value exceeds **80%**, the relay deactivates the pump to stop irrigation. This mechanism maintains soil moisture within the optimal range required for chili plant growth. To demonstrate the implementation of the Median Filtering algorithm, three different soil conditions were tested. The measurement results obtained from the four soil moisture sensors and the calculated median values are presented in Table 1.

Table 1. Soil Moisture Sensor Measurements Using Median Filtering

No	Soil Condition	Sensor 1 (%)	Sensor 2 (%)	Sensor 3 (%)	Sensor 4 (%)	Median Filter
1.	Dry	32	35	33	34	33,5
2.	Optimal	62	65	63	64	63,5
3.	Wet	84	86	85	83	84,5

The experimental results indicate that the Median Filtering algorithm successfully produced representative soil moisture values for each soil condition. Under dry soil conditions, the median value was **33.5%**, indicating that irrigation should be activated because the moisture level was below the predefined threshold. Under moist soil conditions, the median value was **63.5%**, which falls within the optimal moisture range for chili plant growth. Under wet soil conditions, the median value reached **84.5%**, indicating that irrigation should remain inactive because the soil moisture exceeded the upper threshold. These results demonstrate that the Median Filtering algorithm effectively minimizes the influence of fluctuating sensor readings and provides a more stable soil moisture value for automatic irrigation control.

2.3 System Architecture

The system architecture illustrates the interaction among the hardware and software components of the proposed IoT-based drip irrigation system. Four YL-69 soil moisture sensors function as the primary input devices for measuring soil moisture at different locations around the chili plants, while the DHT22 sensor measures the surrounding air temperature. The collected data are transmitted to the NodeMCU ESP8266, which acts as the main controller of the system. The NodeMCU processes the soil moisture data using the Median Filtering algorithm to obtain a representative soil moisture value. Based on the calculated median value, the NodeMCU controls the relay module to activate or deactivate the DC water pump, enabling automatic drip irrigation according to predefined soil moisture thresholds. In addition to irrigation control, the processed data are displayed locally on the I2C LCD and transmitted via a Wi-Fi network to the Blynk platform. This enables users to monitor soil moisture, air temperature, and pump status remotely in real time through a smartphone. The overall architecture of the proposed IoT-based drip irrigation system is illustrated in Figure 2.

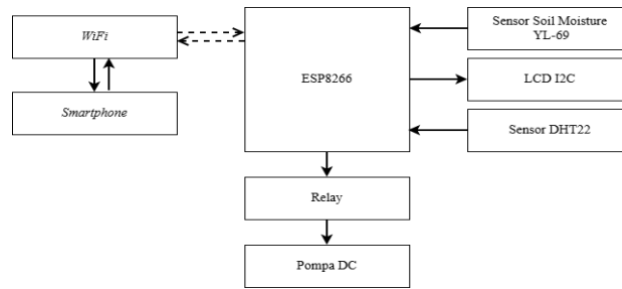


Fig. 2. Block Diagram of the Proposed Monitoring System

2.4 System Flowchart

The system flowchart illustrates the operational workflow of the proposed IoT-based drip irrigation system for chili plants. The process begins with the initialization of the NodeMCU ESP8266, soil moisture sensors, DHT22 temperature sensor, relay module, I2C LCD, Wi-Fi connection, and the Blynk platform. After the initialization process is completed, the system continuously acquires soil moisture data from four YL-69 sensors and temperature data from the DHT22 sensor. The collected soil moisture values are processed using the Median Filtering algorithm to obtain a representative soil moisture value. The calculated median value is then compared with predefined irrigation thresholds. If the median value is below 60%, the relay activates the DC water pump to perform the drip irrigation process. Conversely, if the median value exceeds 80%, the relay deactivates the water pump to stop irrigation. Finally, the soil moisture value, temperature, and pump status are displayed on the I2C LCD and transmitted to the Blynk application through the Wi-Fi network for real time monitoring. The overall workflow of the proposed system is illustrated in Figure 3.

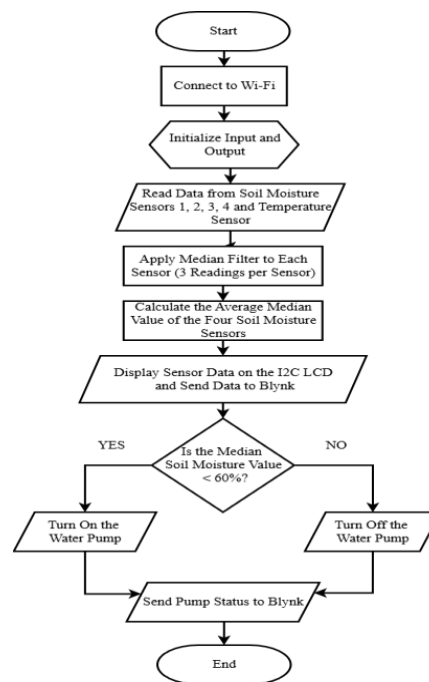


Fig.3. System Flowchart

3. Result and Discussion

This section presents the implementation and evaluation of the proposed IoT-based drip irrigation system for chili plants. The discussion includes the implementation of the hardware and software, the monitoring interfaces, sensor testing, relay and water pump testing, and the overall system performance. The experimental results were analyzed to evaluate the effectiveness of the proposed system in monitoring soil moisture and performing automatic drip irrigation.

3.1 Hardware Implementation

The hardware implementation was carried out by integrating all components of the proposed IoT-based drip irrigation system. The developed prototype consists of a NodeMCU ESP8266 microcontroller, four YL-69 soil moisture sensors, a DHT22 temperature sensor, an I2C LCD, a relay module, a DC water pump, and a drip irrigation system. All components were assembled and tested to ensure proper communication and system functionality.

The NodeMCU ESP8266 functions as the main controller that receives sensor data, processes the Median Filtering algorithm, controls the relay module, and transmits monitoring data to the Blynk platform through a Wi-Fi network. The relay module controls the operation of

the DC water pump according to the calculated soil moisture value, while the I2C LCD displays the monitoring information locally. The implemented hardware configuration of the proposed system is shown in Figure 4.

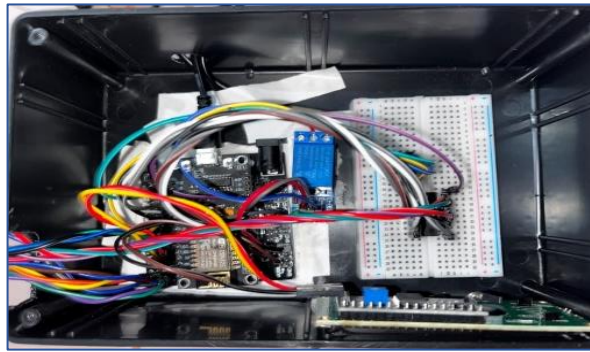


Fig.4. Hardware Implementation

3.2 Software Implementation

The software implementation was developed using Arduino IDE to program the NodeMCU ESP8266. The developed program is responsible for reading soil moisture values from four YL-69 sensors, acquiring temperature data from the DHT22 sensor, processing the Median Filtering algorithm, controlling the relay module, displaying monitoring information on the I2C LCD, and transmitting sensor data to the Blynk platform through a Wi-Fi connection. The developed software continuously performs sensor acquisition and automatic irrigation control according to predefined soil moisture thresholds.

3.3 I2C LCD Interface

The I2C LCD was used as a local monitoring interface to display the soil moisture value, air temperature, and irrigation status in real time. The displayed information allows users to monitor the operating condition of the proposed system directly without accessing the mobile application. Figure 5 shows the I2C LCD interface of the developed system.

Figure 5 illustrates the real-time monitoring information displayed on the I2C LCD. The LCD successfully presents the processed soil moisture value obtained from the Median Filtering algorithm, air temperature measured by the DHT22 sensor, and the irrigation status of the water pump.



Fig. 5: I2C LCD interface

3.4 Blynk Dashboard Interface

The Blynk platform was used as a remote monitoring interface for displaying soil moisture, air temperature, and pump status through a smartphone application. The monitoring data were transmitted from the NodeMCU ESP8266 via a Wi-Fi connection, allowing users to observe the irrigation system remotely in real time. Figure 8 shows the Blynk dashboard interface developed for this study. The application successfully displayed all monitoring parameters and reflected the current operating status of the irrigation system.



Fig. 6: Blynk Dashboard Interface

3.5 Soil Moisture Sensor Testing

The soil moisture sensors were tested to evaluate their ability to measure soil moisture under different soil conditions. Four YL-69 soil moisture sensors were installed at different locations around the chili plants to obtain representative soil moisture measurements. The sensor readings were then processed using the Median Filtering algorithm before being used for irrigation control.

Based on the testing results, the four soil moisture sensors successfully measured different soil moisture conditions. The Median Filtering algorithm produced representative soil moisture values of **33.5%**, **63.5%**, and **84.5%** for dry, optimal, and wet soil conditions, respectively. These values were subsequently used by the NodeMCU ESP8266 to determine the irrigation status. The results indicate that the proposed monitoring system is capable of providing stable soil moisture measurements for automatic drip irrigation.

3.6 Median Filter Testing

The Median Filtering algorithm was tested to evaluate its effectiveness in processing soil moisture data obtained from the four YL-69 sensors. The algorithm was applied to reduce fluctuations in sensor readings caused by environmental conditions and differences in soil moisture at each measurement point. The processed median value was then used as the reference for controlling the automatic drip irrigation system.

3.7 Relay and Water Pump Testing

The relay and DC water pump were tested to evaluate the automatic irrigation performance of the proposed system based on the processed soil moisture values. The relay functions as an electronic switch controlled by the NodeMCU ESP8266, while the DC water pump supplies water to the drip irrigation system according to the predefined soil moisture thresholds.

3.8 Blynk Monitoring Testing

The Blynk application was tested to evaluate its ability to display real-time monitoring data transmitted by the NodeMCU ESP8266 through a Wi-Fi connection. The application functions as a remote monitoring platform, allowing users to observe soil moisture, air temperature, and water pump status using a smartphone.

The testing results showed that all monitoring parameters were successfully transmitted and displayed on the Blynk dashboard without significant delay. The displayed soil moisture values corresponded to the processed data obtained from the Median Filtering algorithm, while the air temperature measured by the DHT22 sensor and the relay status were updated in real time.

3.9 Implementation of the Proposed System

The proposed IoT-based drip irrigation system was successfully implemented and tested on chili plants. The developed prototype integrates the NodeMCU ESP8266, four YL-69 soil moisture sensors, a DHT22 temperature sensor, an I2C LCD, a relay module, a DC water pump, and a drip irrigation system into a single automated irrigation platform. The system continuously monitors soil moisture and environmental temperature while automatically controlling the irrigation process based on the processed sensor data. The implementation results demonstrate that the developed system operated according to the designed workflow. Soil moisture data were successfully collected, processed using the Median Filtering algorithm, and transmitted to the Blynk application for real-time monitoring. The relay module controlled the DC water pump automatically based on the predefined soil moisture thresholds, enabling efficient water distribution through the drip irrigation system.



Fig. 7: Implementation of the proposed monitoring system

4. Conclusion

Based on the design, implementation, and testing of the Internet of Things (IoT)-based drip irrigation system for chili plants, the following conclusions can be drawn:

1. An IoT-based drip irrigation system was successfully designed and constructed using a NodeMCU ESP8266 as the central controller, four YL-69 soil moisture sensors, a DHT22 air temperature sensor, a relay module, a DC pump, an I2C LCD, and the drip irrigation hardware itself. All components operate in an integrated manner, enabling automatic watering of the chili plants based on soil moisture levels.
2. The system is capable of real-time soil moisture monitoring by processing readings from the four YL-69 sensors using a Median Filter method to reduce signal noise. Test results yielded Median Filter values of 35.5% for dry soil, 62% for moist soil, and 87% for wet soil. These results demonstrate that the four YL-69 sensors effectively detect changes in soil moisture, while the application of the Median Filter provides stable values for making watering decisions. Relay and pump testing confirmed that the system successfully stops the pump when soil moisture falls below 60% and stops it when moisture reaches or exceeds 60%.
3. The system was successfully integrated with the Blynk application, allowing real-time monitoring of soil moisture, air temperature, and pump status via smartphone. This integration enables users to monitor plant conditions and track the watering process without needing to be physically present at the site.

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