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Smart Median Guardian: Soil Moisture Monitoring and Automatic Water Dispenser Using IOT

Dr. Kalaiselvi P[1*], Hariharan C[2]
[1*]*Associate Professor, Department of Civil Engineering, AAA College of Engineering and Technology, Sivakasi 626 005, Tamil Nadu, India*
[2]*UG Student, Department of Civil Engineering, AAA College of Engineering and Technology, Sivakasi 626 005, Tamil Nadu, India*

Abstract- The Smart Median Guardian is an IoT-based automated irrigation system designed to efficiently maintain trees along road medians. It uses an ESP32 microcontroller, soil moisture sensor, relay module, and DC motor pump to continuously monitor soil moisture levels and automatically dispense water when the soil becomes dry. The system is integrated with the Blynk mobile application to enable real-time monitoring and remote control of irrigation activities. This approach reduces water wastage, minimizes manual labour, and ensures the healthy growth of urban greenery. By providing timely and precise watering, the project supports roadside tree maintenance, enhances aesthetic appeal, improves air quality, and contributes to environmental sustainability. It is a low-cost, reliable, and scalable solution suitable for urban landscaping and public green spaces.

Keywords: Smart Irrigation, Internet of Things (IoT), Soil Moisture Monitoring, ESP32, Blynk Application, Urban Greenery, Water Conservation.

I. INTRODUCTION

Urban greenery, especially trees planted along road medians, plays a vital role in improving air quality, reducing noise pollution, and enhancing road safety by acting as natural dividers and reducing headlight glare. However, these trees are often neglected after planting, resulting in drying, decay, and the wastage of public resources. Traditional manual watering methods are time-consuming, labour-intensive, and often unreliable, leading to either insufficient or excessive watering.

The lack of real-time monitoring and irregular maintenance schedules significantly affects the growth and health of median trees. To address these challenges, this project proposes the "Smart Median Guardian," a low-cost IoT-based automated soil moisture monitoring and water dispensing system. By utilizing an ESP32 microcontroller and a soil moisture sensor, the system continuously monitors the moisture levels near the tree roots.

The system is designed to automatically control water flow based on real-time data, ensuring that water is dispensed only when necessary. Furthermore, the integration with the Blynk mobile application allows for continuous remote monitoring, reducing the need for physical inspections. This automated approach ensures healthy, sustainable, and resilient urban greenery while conserving water and optimizing maintenance efforts.

II. LITERATURE REVIEW

The development of automated irrigation systems has been a significant area of research to improve water use efficiency and reduce manual intervention in agriculture and urban landscaping.

Sharma et al. (2023) discussed an IoT-based smart irrigation system using ESP32. Their study highlighted that ESP32-based systems provide reliable real-time soil moisture monitoring with Wi-Fi connectivity, significantly reducing water wastage compared to timer-based systems.

Lee & Park (2022) explored cloud-integrated irrigation monitoring systems. They found that cloud platforms enable continuous data logging and remote control, which are essential for managing distributed infrastructure like road medians.

Singh et al. (2021) focused on IoT platforms for remote monitoring and demonstrated that the Blynk IoT platform effectively enables real-time alerts, live sensor visualization, and remote pump control, improving overall system efficiency.

Gupta & Verma (2020) emphasized the importance of real-time soil moisture monitoring systems. Their work confirmed that integrating soil moisture sensors with microcontrollers ensures accurate irrigation control, preventing both over-watering and under-watering of plants.

Kaur et al. (2020) presented findings on IoT-based soil monitoring, concluding that automated monitoring helps conserve water and improves plant health through timely irrigation.

Recent studies have also highlighted the integration of smart city concepts with greenery management (Rao & Kumar, 2018), where IoT-enabled systems contribute to the sustainable maintenance of public green spaces. Despite these advancements, there is a gap in low-cost, specific solutions designed for the unique constraints of roadside median maintenance, which this project aims to address.

III. PLANNING AND ARCHITECTURE

The planning of the Smart Median Guardian focuses on developing a robust, standalone system capable of operating in outdoor environments. The primary objective is to automate the irrigation process for median trees based on accurate soil moisture feedback.

During the planning phase, the root zone of median trees is identified as the critical location for sensor placement to ensuring representative moisture readings. The system architecture is built around the ESP32 microcontroller due to its dual capability of processing sensor data and transmitting it via Wi-Fi.

The architecture involves a feedback loop:

1. Sensing: The soil moisture sensor detects the water content.
2. Processing: The ESP32 compares the reading against a pre-set threshold (e.g., moisture < 25%).
3. Action: If the soil is dry, the Relay Module is triggered to turn on the DC Water Pump.
4. Communication: The status (Moisture Level, Pump Status) is transmitted to the Blynk cloud server.
5. User Interface: The Blynk App displays the data and allows for manual override if necessary.

Power supply planning includes the use of a standard adapter or a potential solar panel integration to ensure sustainable off-grid operation on road medians.

IV. MATERIALS AND SOFTWARE USED

The proposed system consists of a combination of hardware components and software tools selected for their cost-effectiveness and reliability.

Hardware Components:

- ESP32 Microcontroller: The central processing unit that reads sensor data, executes the control logic, and manages Wi-Fi communication.

Figure1 : ESP32 module

It is chosen for its low power consumption and high processing speed.

- Soil Moisture Sensor: A capacitive type sensor is used to measure the volumetric water content of the soil.

Figure2 : Soil Moisture Sensor

Unlike resistive sensors, capacitive sensors are corrosion-resistant, making them suitable for long-term burial in soil.

- Relay Module: An electromechanical switch that acts as a bridge between the low-voltage ESP32 (3.3V) and the higher voltage required by the water pump.

Figure 3 : Relay Module

It physically switches the pump ON or OFF based on signals from the ESP32.

- DC Water Pump: A submersible mini pump used to dispense water from a reservoir to the tree roots.

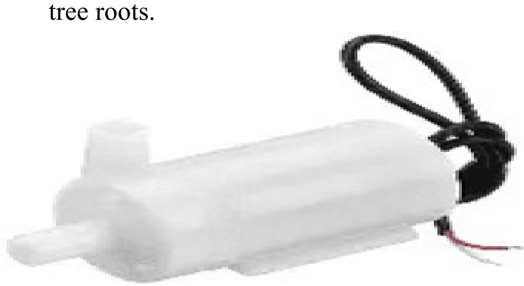

Figure 4 :DC Submersible Mini pump

- Power Supply: Used to power the ESP32 and the pump.

Software Tools:

- Arduino IDE: Used for programming the ESP32 microcontroller. The code handles sensor calibration, threshold logic, and Wi-Fi connectivity.
- Blynk IoT Platform: A mobile application interface used for real-time monitoring. It features widgets like Gauges for moisture levels and Buttons for manual pump control.

V. Methodologies

The methodology adopted for the Smart Median Guardian involves a systematic approach from sensor installation to cloud integration.

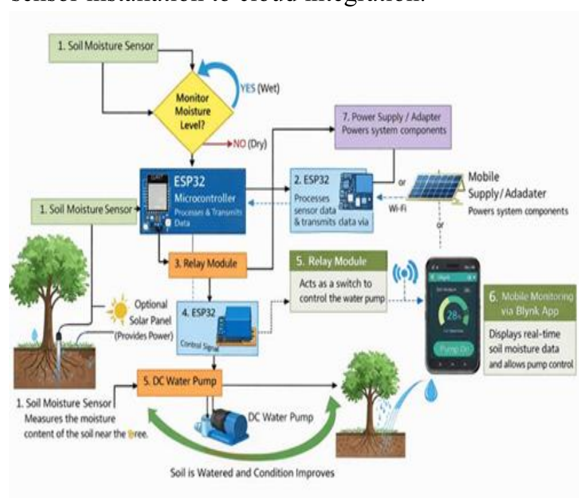

Figure 5 : Block Diagram

Step 1: Sensor Placement
The soil moisture sensor is inserted into the soil near the root zone of the plant. This ensures that the system measures the moisture available to the roots rather than just surface wetness.

Step 2: Data Acquisition

The ESP32 microcontroller continuously reads analog signals from the moisture sensor. These raw values (typically 0-4095) are mapped to a percentage scale (0% to 100%) to represent soil moisture content.

Step 3: Decision Making (Threshold Logic)

The system uses predefined threshold values to make autonomous decisions:

- Dry Condition: If Moisture < 25%, the soil is considered dry.
- Wet Condition: If Moisture > 75%, the soil is considered sufficiently wet.

Step 4: Automatic Control
Based on the decision logic:

- When the soil is Dry (<25%), the ESP32 sends a HIGH signal to the Relay Module, switching the Water Pump ON.
- When the soil reaches the Wet threshold (>75%), the ESP32 sends a LOW signal to the Relay, switching the Water Pump OFF.

Step 5: IoT Monitoring and Alert Generation
Simultaneously, the ESP32 transmits the real-time moisture percentage and pump status to the Blynk cloud.

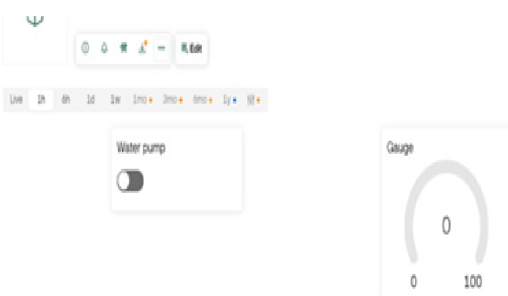

Figure 6 : Blynk Interface

Users can view this data on their smartphones. If the moisture level drops critically low, the system can be configured to send a push notification to the user.

Step 6: Power Supply and Sustainability

For field deployment, the system is designed to be powered by a battery or solar panel setup, ensuring continuous operation without reliance on grid electricity.

VI. RESULTS AND ANALYSIS

The prototype was successfully assembled and tested. The ESP32 successfully established a connection with the Blynk server and transmitted data in real-time.

Monitoring Performance:

The Blynk dashboard provided a clear visualization of the soil conditions. A Gauge widget displayed the live moisture percentage, and an LED widget indicated the pump status.

- Dry Soil Test: When the sensor was placed in dry soil, the reading dropped below 25%. The system immediately triggered the relay, turning the pump ON. The dashboard updated the status to "Pump: ON".
- Wet Soil Test: As water was dispensed, the moisture reading increased. Upon exceeding the 75% threshold, the pump automatically turned OFF, preventing water wastage.

Data Accuracy:

The capacitive moisture sensor provided stable readings with minimal fluctuation. The correlation between the physical soil condition (dry/wet) and the digital readings on the app was consistent, validating the reliability of the system.

Efficiency:

The automation logic successfully eliminated the need for manual intervention. The system demonstrated that it could maintain soil moisture within the optimal range (25% - 75%) autonomously.

VII. DISCUSSION AND VALIDATION

The implementation of the Smart Median Guardian demonstrates that IoT technology can effectively solve the problem of maintaining roadside greenery. The system's ability to "self-water" based on actual soil needs rather than a fixed timer ensures that water is not wasted during rainy days and that plants are not neglected during hot summer days.

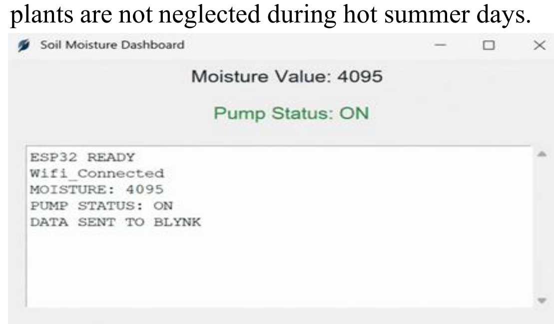

Figure 7: Arduino Ide Output

The use of the Blynk app provides a significant advantage over traditional systems by adding a layer of transparency and remote manageability.

Municipal workers can monitor the status of miles of road medians from a single control room.

The tests validated the stability of the ESP32 in handling both sensor data processing and Wi-Fi communication simultaneously. The threshold-based control logic proved effective in preventing waterlogging and ensuring adequate hydration. Future iterations could include a water level sensor for the tank to alert users when the water reservoir needs refilling.

VIII.CONCLUSION

The Smart Median Guardian project successfully achieved its aim of designing a low-cost, automated irrigation system for road medians. By integrating the ESP32 microcontroller with soil moisture sensors and the Blynk IoT platform, the system provides a robust solution for urban greenery maintenance.

Key achievements include:

1. Water Conservation: Dispensing water only when the soil is dry.
2. Labor Reduction: Automating the watering process and enabling remote monitoring.
3. Real-Time Data: Providing instant visibility into soil health via mobile app.

This system serves as a scalable model for smart city infrastructure, potentially extending the lifespan of median trees and optimizing the use of public resources.

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