SMART IRRIGATION SYSTEM USING IOT

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ABSTRACT: This abstract outlines a comprehensive smart irrigation system integrated with a mobile application for remote monitoring and control. The system incorporates hardware components such as Arduino, NodeMCU, GSM 800C, soil moisture and weather sensors, an automatic valve, an automatic pump, a water flow sensor, an ESP32 camera, and a solar panel. Data from these components is processed and transmitted to a cloud database (Firebase) via NodeMCU and GSM for storage and retrieval. The mobile application offers three operation modes: **Automatic**, **Automatic Mode Off**, and **Manual**. In **Automatic Mode**, the system autonomously manages irrigation based on predefined conditions, activating the valve and pump as needed. In **Automatic Mode Off**, the app alerts users when irrigation is required, allowing for manual intervention if desired. In **Manual Mode**, users can directly control hardware components, such as activating the pump and valve or monitoring fields through the camera. This seamless integration of the mobile application and hardware enables real-time data access on soil moisture, weather conditions, pump and valve status, and field monitoring. By leveraging automation and smart decision-making, the system optimizes water usage, enhances crop yield, and minimizes manual intervention, addressing water scarcity and promoting sustainable agriculture.

Keywords smart irrigation system, soil moisture, crop yield, water scarcity, agriculture.

I. INTRODUCTION

In the face of growing water scarcity and the need for sustainable agricultural practices (Schupp & Sharp 2012, Penzenstadler *et al.,* 2018), smart irrigation systems have emerged as a transformative solution (Marcu *et al.,* 2019). These systems blend cutting-edge technology with traditional farming methods (Thamaraimanalan *et al.,* 2018), offering precise control over water usage in agricultural and landscaping applications. By integrating advanced components such as sensors, data analytics, and automation, smart irrigation systems optimize water distribution (Kansara *et al.,* 2015). They collect real-time data on soil moisture, weather conditions, and plant water requirements to ensure water is delivered efficiently, reducing waste and maximizing crop yields.

The advantages of these systems extend beyond water conservation and crop health. They provide significant cost savings by lowering water bills and maintenance costs, while also promoting environmental sustainability by reducing the ecological impact of water use. This introduction explores the key components, benefits, and far-reaching implications of smart irrigation systems, highlighting how they are revolutionizing water management practices and driving a more sustainable future for agriculture and landscaping.

Rafi *et al.,* proposed an automated irrigation system utilizing soil moisture and rain sensors to optimize the irrigation process. This system could measure soil water content, detect rainfall, and determine the precise amount of water required for irrigation, controlling pumps accordingly. It was designed to accommodate both large-scale and small-scale irrigation setups and could be connected to a central computer for monitoring and control. By reducing water wastage and mitigating water stress in agricultural areas, the system was both efficient and cost-effective. However, as previously mentioned, overwatering poses a significant risk to plants. While automatic systems are highly suitable for extensive agricultural fields, they may not be ideal for rooftop or balcony gardens due to their lack of precision in such settings.

Rajashekar Reddy Chinta 2015, introduced a low-cost smart irrigation control system designed to enhance water usage efficiency for farms and crops. This system incorporated ultraviolet (UV) light disinfection as a water treatment mechanism to eliminate microbiological contaminants. The system, based on an Arduino board and a soil moisture sensor, was developed to automate irrigation and maximize crop yield. The Arduino board was programmed to send alerts to farmers when soil moisture levels dropped below a predefined threshold. It could also control irrigation pumps and valves, thereby conserving water, reducing labor and energy costs, and improving crop productivity. Furthermore, the system allowed for precise control of irrigation cycles, including their frequency and duration, to optimize water use. It also measured the water used for irrigation, enabling farmers to monitor and refine their water management practices effectively. This cost-effective solution offered significant advantages for sustainable agriculture, particularly in resource-constrained settings.

Ahmed *et al.,* 2020, proposed a groundbreaking IoT-based automatic plant watering system utilizing soil moisture sensing to support farmers in rural India. This system aims to enhance farmers' productivity by providing an automated and efficient method to monitor and water their crops. It uses IoT sensors to measure soil moisture levels and automatically activates irrigation systems when moisture falls below a certain threshold. This approach conserves water while boosting crop yields. Additionally, the system provides farmers with real-time data on soil moisture, enabling informed irrigation decisions. Designed to be low-cost and user-friendly, it is accessible to rural farmers. The system is energy-efficient, with the potential for solar power integration, making it a sustainable solution. By automating irrigation and offering data-driven insights, this system can revolutionize farming in rural India, leading to improved yields and better livelihoods. It incorporates Blynk, an IoT platform for Android smartphones, to control devices like Arduino, Raspberry Pi, and NodeMCU via the Internet.

Kodali & Sarjerao 2017, introduced a "Low-Cost Smart Irrigation System Using MQTT Protocol" to minimize water wastage and enhance crop productivity. The system leverages MQTT as the messaging protocol for IoT and includes an LDR sensor to measure light intensity. A soil moisture sensor and an Arduino microcontroller measure soil conditions and transmit the data to a web server via MQTT. The system also features an Android application that allows users to remotely control the irrigation process. With automatic irrigation based on soil moisture levels and user preferences, the system reduces water waste while improving crop yields. Real-time feedback provided by the app enables users to optimize irrigation settings for greater efficiency. This cost-effective system is a practical and efficient tool for sustainable agriculture.

Ali *et al.,* 2020, developed an IoT-based smart garden monitoring system utilizing a NodeMCU microcontroller. This system incorporates a TFT screen to display readings from moisture, temperature, and humidity sensors, with the same data accessible via a mobile application. The system monitors environmental conditions, such as soil moisture and temperature, transmitting data to a cloud platform for user access. Alerts are sent via SMS or email when soil moisture is too low or temperature is too high, ensuring timely action. The system also features an integrated irrigation module that can be remotely controlled and programmed for scheduled watering. Additionally, users can monitor the system’s energy consumption through the app. This system is an ideal solution for gardeners seeking remote monitoring and management, combining efficiency and convenience in garden care.

The main objectives of this model are summarized as follows:

1. Enable real-time monitoring and automation using IoT.
2. Integrate cloud-based data storage for analysis and decision-making.
3. Provide remote control capabilities through a mobile application.
4. Customize irrigation practices based on crop-specific water requirements.
5. Enhance sustainability and resource efficiency in agriculture.

II. PROPOSED METHOD

Implementing a smart irrigation system requires the integration of advanced technologies to effectively manage water usage in agriculture or landscaping. The process begins with installing soil moisture sensors across the field or garden to measure soil moisture levels. These sensors wirelessly transmit data to a central control system. Additionally, weather data from local stations or APIs is gathered, providing valuable insights into temperature, humidity, wind speed, and rainfall.

This data, along with historical patterns, is processed using algorithms to predict optimal watering schedules. A central control unit—typically based on microcontrollers like Arduino or Raspberry Pi—analyzes this information and manages actuators and valves to regulate irrigation. Users interact with the system through a user-friendly interface, such as a web or mobile app, which allows them to monitor sensor data, adjust settings, and receive alerts.

By seamlessly integrating sensors, weather data, control units, and user interfaces, smart irrigation systems enable precise water management, fostering healthier plant growth and conserving valuable resources.

A. SYSTEM DESIGN

The design of a smart irrigation system integrates several key components to efficiently manage water resources and promote plant health. At its core is a network of strategically placed soil moisture sensors, complemented by environmental sensors that capture data on temperature, humidity, and light intensity. This sensor data, combined with weather forecasts from local stations or APIs, is processed using advanced algorithms.

A central control unit analyzes this data to generate an optimized irrigation schedule, precisely managing solenoid valves through actuators to deliver water to specific zones as needed. A user-friendly interface—accessible via web or mobile applications—enables users to monitor sensor readings, adjust settings, and receive timely alerts. Remote access capabilities enhance convenience, allowing users to manage irrigation operations from anywhere.

The system's reliability and adaptability are ensured through continuous testing, optimization, and integration with existing infrastructure. By accommodating varying environmental conditions, the system promotes sustainable water management while supporting healthy, thriving vegetation.

In this study, a smart irrigation system was designed, implemented, and tested. The integration of an LCD, water pump, solenoid valve, soil moisture sensor, and weather sensor with a NodeMCU was performed as part of the hardware setup. Each component was wired to the appropriate pins of the NodeMCU following their technical specifications to ensure proper operation.

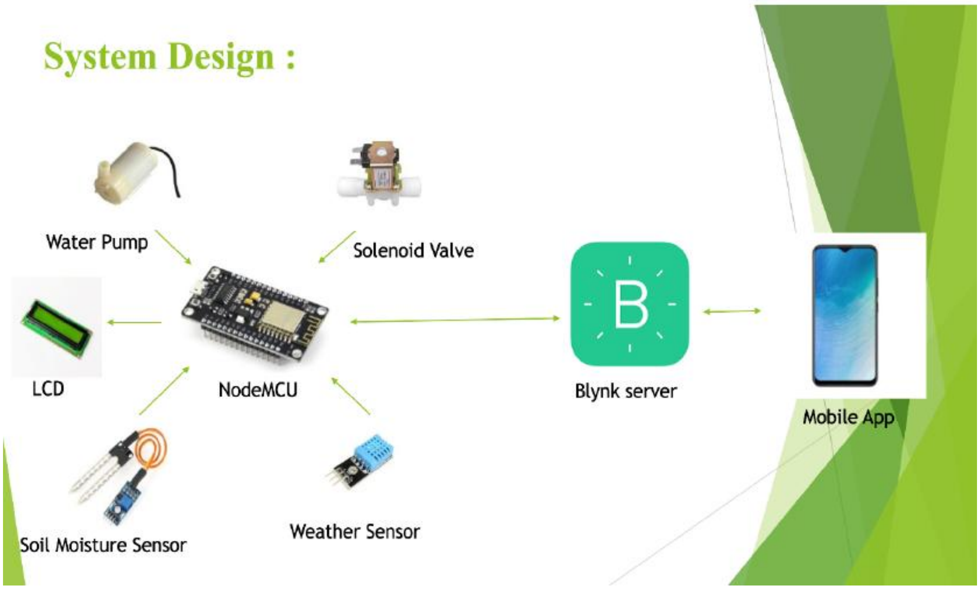

Figure 1. System Design

For remote monitoring and control, the Blynk app was utilized. A new project was created in the app, and the Blynk Auth Token was generated to establish communication with the NodeMCU. Widgets were configured in the Blynk app to enable real-time monitoring and control of the system's components.

The software development was carried out using the Arduino IDE. The Blynk library for ESP8266 was employed to connect the NodeMCU to the Blynk server. Custom functions were implemented to:

- Read and process data from the soil moisture sensor and weather sensor.
- Control the water pump and solenoid valve based on predefined thresholds.
- Display real-time data on the LCD.

After coding, the firmware was uploaded to the NodeMCU, and extensive testing and debugging were performed. The Blynk app interface was used to validate system functionality by monitoring sensor readings and controlling actuators. Any issues encountered during testing were resolved to ensure the system's reliability.

This implementation demonstrates the feasibility of integrating IoT-based technologies for efficient irrigation management.

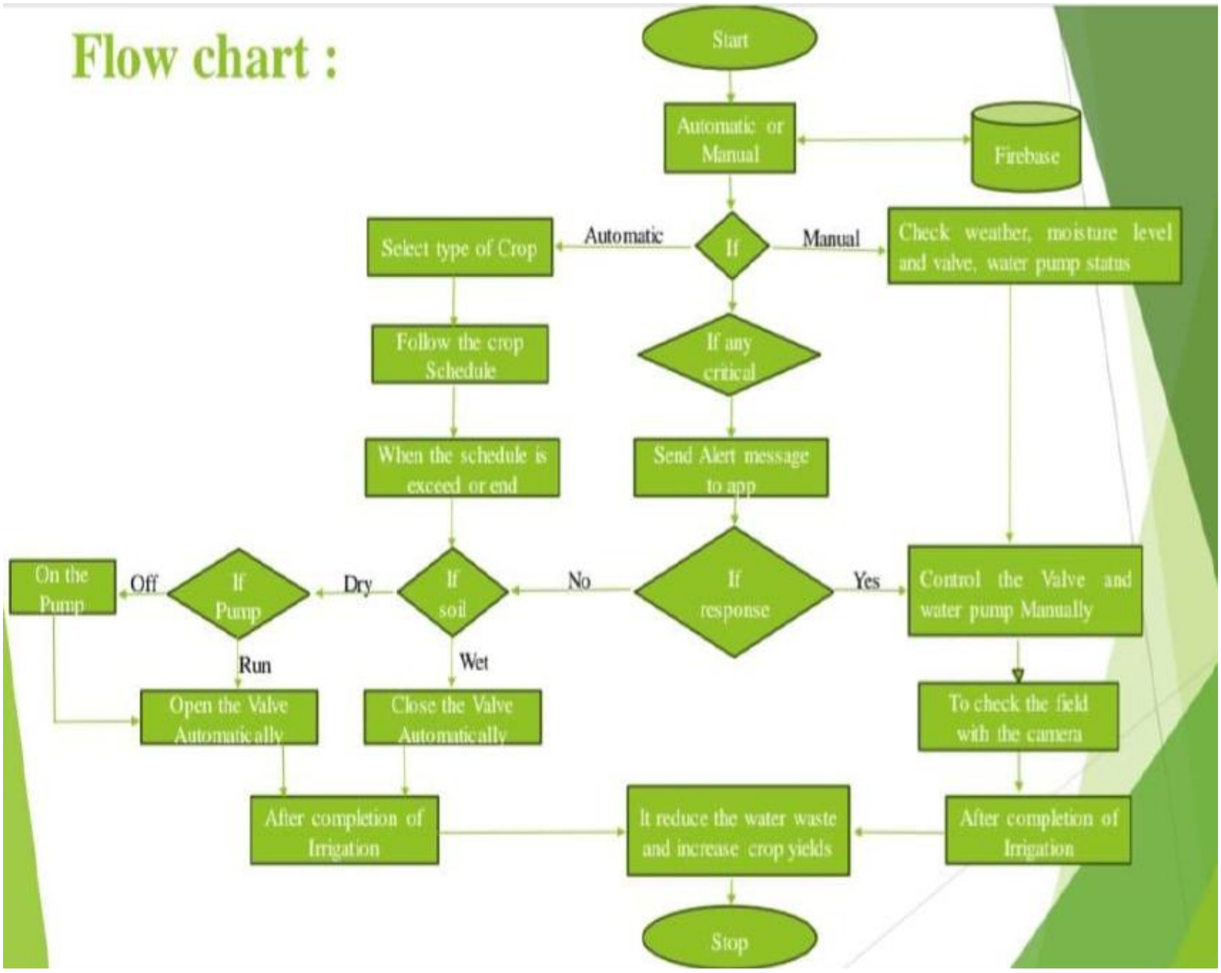

Figure 2. Flow Chart

Development of Automatic Mode Activation in Response to Alerts

To enhance the functionality of the smart irrigation system, an automatic mode activation feature was integrated. This feature was designed to respond to unacknowledged alert messages within the Blynk app. The implementation process involved the following steps:

1. **Alert Detection and Monitoring:**
   A function was developed within the NodeMCU's firmware to detect alert messages sent to the Blynk app. These messages were monitored for specific keywords or patterns indicating alert conditions.
2. **Timer Integration for Automatic Mode Activation:**
   Upon detecting an alert, a timer was initiated to measure the elapsed time since the alert was sent without acknowledgment from the user. If the timer exceeded a predefined threshold, the system automatically transitioned to automatic mode, ensuring uninterrupted operation.
3. **User Interaction and Override Capabilities:**
   Interactive elements, including buttons and switches, were added to the Blynk app

interface. These allowed users to acknowledge alerts directly, preventing automatic mode activation if addressed in time. Additionally, users were given the option to manually override automatic mode activation, providing greater control over the system.

4. **System State Awareness:**
   The Blynk app interface was updated to display the current operational mode (manual or automatic). This ensured that users remained informed about the system's status, enhancing usability and transparency.
5. **Error Handling and Robustness:**
   Comprehensive error handling mechanisms were implemented to address potential issues, such as communication failures or unexpected conditions. This ensured the system's reliability and stability during operation.

The integration of these features allowed for a seamless transition between manual and automatic modes, improving the system's adaptability to varying user interactions and environmental conditions.

B. IMPLEMENTATION

The implementation of the smart irrigation system follows a systematic methodology aimed at optimizing water management through seamless integration of multiple components. Initially, soil moisture sensors are deployed throughout the targeted area to monitor soil conditions, providing real-time data on moisture levels. Complementing this, weather data gathered from local weather stations or APIs offers additional context by tracking environmental factors such as temperature, humidity, and rainfall. This data is processed using advanced algorithms designed to calculate optimal irrigation schedules based on plant needs and current weather conditions.

The central control system processes the data and adjusts the operation of actuators and solenoid valves, controlling water flow to specific zones and ensuring precise irrigation delivery. The system is designed with a user-friendly interface that can be accessed via web or mobile applications, enabling users to monitor the system’s status, adjust settings, and receive notifications or alerts. Additionally, remote access features enable real-time management of the irrigation system from any location with internet connectivity.

Through rigorous testing and continuous optimization, the system is fine-tuned for reliability and efficiency, providing an effective solution for sustainable water use while promoting healthier plant growth. This comprehensive approach ensures that the system not only meets the immediate needs of vegetation but also contributes to long-term sustainability in water resource management.

C. INTEGRATION OF MANUAL MODE IN SMART IRRIGATION SYSTEM

In the development of the smart irrigation system, incorporated a **manual mode** to provide users with full control over the system's operation. This manual mode allows users to override the automated irrigation system and directly control the hardware components through the **Blynk app**. The implementation of manual control involved the following steps:

1. **User Input via Blynk App**:
    - Functions were created to enable the manual control of the **water pump** and **solenoid valve**, responding to user commands transmitted through Blynk widgets such as buttons and switches.
    - These widgets were mapped to virtual pins on the NodeMCU, enabling the user to toggle between **manual mode** and **automatic mode** and directly control hardware components.
2. **Manual Control Functions**:
    - Dedicated functions were designed to interpret the Blynk widget input and adjust the state of the water pump and solenoid valve accordingly. This direct control ensures that the system responds instantly to user input, giving full autonomy over the irrigation process.
3. **Real-Time Feedback**:
    - The Blynk app provides visual feedback to users, displaying the current operational status of the hardware components. For instance, users can view whether the water pump is running or if the valve is open, allowing them to monitor and manage the system in real-time.
4. **Safety Measures**:
    - To ensure the safety and reliability of manual operations, several precautions were implemented:
        - **Confirmation prompts** are triggered before executing critical actions, such as turning the water pump on or opening the valve.
        - **Usage limits** were set to prevent excessive resource consumption, ensuring that the system operates within safe and sustainable parameters.
5. **Seamless Switching Between Modes**:
    - The system was designed to allow users to seamlessly switch between manual and automatic modes. In **automatic mode**, the system operates autonomously based on sensor data and weather conditions, ensuring optimal irrigation.

- In **manual mode**, users have the flexibility to take control of the system, overriding the automated settings whenever necessary. This dual-mode operation enhances user flexibility and control over the irrigation process.

6. **System Benefits**:
   - The integration of manual mode provides users with the autonomy to manage irrigation tasks directly, while still benefiting from the **automatic mode's** efficiency. This approach ensures the system is both **user-friendly** and **secure**, with ample flexibility for various usage scenarios.

Figure 3. Manual Mode.

C. INTEGRATION OF AUTOMATIC MODE IN SMART IRRIGATION SYSTEM

In this study, designed and implemented the **automatic mode** for a smart irrigation system that autonomously manages irrigation based on real-time environmental conditions. The automatic mode was developed to optimize plant growth while minimizing water usage. The following components were integrated into the system:

1. **Sensor Integration**:
   - Soil moisture sensors and weather sensors were employed to monitor soil moisture and environmental conditions, such as temperature.

- The soil moisture sensor provides real-time data on soil moisture levels, while the weather sensor tracks temperature, which serves as a key factor in determining the irrigation needs.

2. **Threshold Setting**:
   - Thresholds were established for both soil moisture and temperature. If the soil moisture falls below a predefined threshold or if the temperature exceeds a certain level, the system is programmed to activate the irrigation components.
3. **Automatic Mode Control Function**:
   - The automaticModeControl() function was implemented to control the system's irrigation behavior autonomously. This function processes the sensor readings and compares them to the established thresholds:
     - When the sensor data meets the criteria for irrigation, the water pump and solenoid valve are activated.
     - When conditions are within optimal range, the pump and valve are turned off to prevent overwatering.
4. **Continuous Monitoring and Execution**:
   - The automaticModeControl() function runs continuously within the main loop of the program, ensuring real-time monitoring and adjustment of the irrigation system. This constant monitoring allows the system to respond dynamically to changing environmental conditions.
5. **User Interface and Feedback**:
   - The system was integrated with the Blynk app to provide real-time monitoring and user control. The app displays live data from the sensors, as well as the status of the irrigation system. Additionally, users can toggle between automatic and manual modes via the app, offering flexibility and control.
6. **Results and Benefits**:
   - The automatic mode ensures that the irrigation system responds efficiently to changes in soil moisture and temperature, promoting optimal plant growth and reducing water wastage. The seamless integration of sensor data, threshold logic, and user control allows for effective and sustainable water management.

In this work, developed a smart irrigation and gardening system designed to simplify the tasks of gardeners, particularly for those with limited time or those engaged in plant or crop research. The integration of Internet of Things (IoT) technologies enables users to monitor and control the irrigation process remotely, enhancing both convenience and efficiency. By incorporating sensors to measure soil moisture and humidity levels, our system ensures that plants are watered only when necessary, preventing overuse of water and promoting healthy growth.

Figure 4. Automatic Mode.

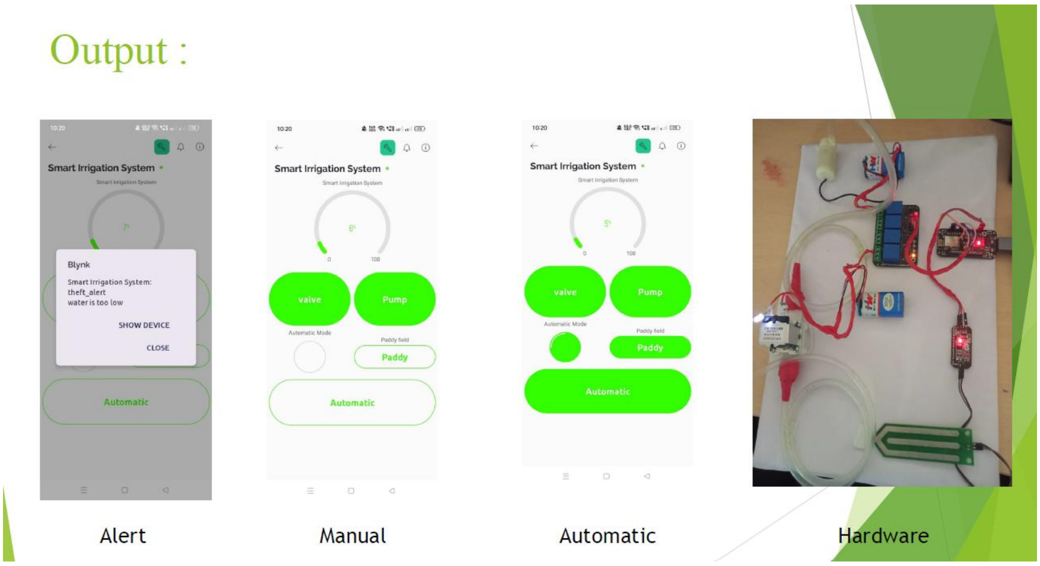

Figure 5. Output.

VI. CONCLUSION AND FUTURE ENHANCEMENT

A. CONCLUSION

The automation features of the system, including the ability to set watering schedules and trigger alerts for extreme soil conditions, further contribute to a user-friendly experience. Users no longer need to manually adjust the system, as it can automatically turn on and off based on real-time data. Alerts can notify users when the soil is too dry or when environmental conditions, such as temperature, are unfavourable for plant growth.

The developed system provides a valuable resource for individuals interested in gardening, from planting and caring for trees to preventing plant diseases and analyzing soil quality. With its seamless integration of IoT technologies, the system eliminates guesswork in daily gardening tasks, particularly in irrigation management. Ultimately, we believe that this smart irrigation platform offers a significant contribution to sustainable farming practices and provides an efficient solution for modern gardening needs.

B. FUTURE ENHANCEMENT

The development of this smart irrigation and gardening system lays a strong foundation for future improvements and broader applications. The following enhancements are envisioned to further improve its efficiency and versatility:

- **Enhanced Disease and Dryness Detection**: Future versions of the system will integrate advanced object detection techniques to identify a broader range of plant diseases and monitor varying degrees of plant dryness. By incorporating machine learning models and image recognition, the system will be able to provide real-time diagnoses, alerting users to potential issues before they become severe.
- **Integration with Water Management Systems**: The system can be adapted to interface with existing water management systems, such as water tanks and reservoirs. By doing so, it will allow for more efficient water distribution, ensuring that water is used optimally across different zones. This integration can help minimize water wastage and contribute to sustainable water practices.
- **Versatility Across Plant Types**: In future iterations, the system will be enhanced to ensure compatibility with a wider range of plant species, from vegetables to ornamental plants. The aim is to create a more versatile tool that can cater to diverse agricultural environments, including both small-scale and large-scale farming operations. This enhancement will also involve adjusting soil moisture thresholds and other parameters to suit the unique needs of different plant types.

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