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An Intelligent Soil Moisture Monitoring and Irrigation System for Indoor Cultivation

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Abstract: Efficient irrigation management remains one of the most critical and labor-intensive operations in agriculture and indoor gardening. Watering practices must be carefully regulated irrespective of climatic variability, including high-temperature dry conditions or excessive humidity. Improper irrigation scheduling and inaccurate water quantity control can lead to overwatering, root diseases, nutrient leaching, or water stress, ultimately affecting plant growth and yield. Therefore, precise monitoring of soil moisture levels and environmental parameters is essential to ensure optimal plant health and sustainable water utilization. To address the limitations of manual irrigation—particularly the uncertainty associated with determining the appropriate timing and volume of water application—this study proposes the design and implementation of an Indoor Gardening Irrigation System based on automated sensing and control mechanisms. The system eliminates the need for continuous human supervision by integrating soil moisture sensing, environmental monitoring, and intelligent water delivery control. By automating irrigation decisions, the system enhances plant growth efficiency while significantly reducing water wastage. The proposed architecture employs the ESP8266 NodeMCU microcontroller as the central processing unit due to its integrated Wi-Fi capability and low power consumption. A soil moisture sensor continuously measures the volumetric water content of the growing medium. The microcontroller is programmed with predefined threshold values corresponding to specific plant water requirements. When the detected moisture level falls below the programmed threshold range, the system automatically activates a water pump through a relay-controlled pipeline distribution network. Irrigation continues until the soil moisture level returns to the optimal range, ensuring precision watering based on real-time feedback. In addition to soil monitoring, a DHT11 sensor is incorporated to measure ambient temperature and relative humidity. These environmental parameters provide contextual data that can influence irrigation frequency and evapotranspiration rates. The system also includes a liquid crystal display (LCD) module for real-time local visualization of sensor readings and system status. For remote monitoring and user interaction, the system integrates IoT functionality through the ESP8266's Wi-Fi interface. Sensor data and irrigation status updates are transmitted to a mobile platform such as Telegram via a cloud-based communication protocol. This enables users to receive real-time notifications, monitor environmental conditions, and supervise irrigation activities remotely. Overall, the developed system provides a smart, energy-efficient, and water-conserving irrigation solution tailored for indoor gardening environments. By combining embedded systems, IoT communication, and sensor-based feedback control, the proposed framework improves irrigation accuracy, enhances plant productivity, and promotes sustainable resource management.

Keywords: Indoor Gardening, Smart Irrigation System, ESP8266 NodeMCU, Soil Moisture Sensor, DHT11 Sensor, Internet of Things (IoT), Automated Watering System, Precision Agriculture, Environmental Monitoring, Water Conservation.

I. INTRODUCTION

This research focuses on the issues mentioned today to meet all technical and economic aspects. This project presents soil moisture monitoring using a controller with a WiFi module to monitor soil moisture, temperature and humidity. The project works fully automatically measuring the moisture reduction of existing plants to operate the irrigation system, restoring water as needed while minimizing excess water use. "Indoor Gardening Irrigation System" also uses a more efficient and simple solution based on technology "Internet of Things (IOT)". The built model is used to detect soil moisture, temperature & humidity, data uploaded via the Internet analyzed. In the existing water irrigation monitoring system, only the soil moisture sensor is used, not the temperature & humidity sensor. It also requires labor to operate the system, knowing when and how much to water are two important aspects of the watering process. Therefore, developing a soil moisture monitoring system is very important to monitor plants in the future.

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II. PROBLEM STATEMENT

Irrigation is an important thing in a gardening system. The water we provide, which is the main element, will ensure that the plants survive in certain conditions. As we all know, most gardeners use manual methods for their traditional irrigation but this system is inefficient and because, the water is irrigated directly in the soil, grow- plants experience high stress from variations in soil moisture, therefore plant appearance is poor. Plants will either die if the water supply is not sufficient for the plants or vice versa. In their daily activities many people often forget to water their plants and thus it becomes challenging for them to keep their plants healthy and alive. Also it is a challenge for gardeners to maintain their plants and manage the watering of plants during water shortages. To maintain the situation and overcome the problem, "Indoor Gardening Irrigation System" is used. This will not require manpower and time if using an automatic watering method instead of manual. Less Irrigation previously did not include any kind of data about temperature & soil moisture to the plant. Sensors such as temperature sensors and soil moisture detectors are used to control temperature, soil moisture and watering in the gardens. This system also has the capacity to monitor the condition of the garden remotely from a Smartphone by using an IoT module. Information will be sent using wifi and data will be displayed using in telegram and LCD. So users will know the state of their garden anywhere.

III. PROJECT OBJECTIVES

Monitor soil moisture and environmental conditions using a Soil Moisture Sensor and a DHT11 sensor.

Control a DC pump motor to automate plant watering based on sensor readings.

Send sensor updates and pump status to the user via the Telegram app for remote monitoring.

Provide real-time data display through an LCD screen.

IV. PROJECT SCOPE

This project operates automatically when it is turned on. To carry out its operation, this project uses Esp 8266 Nod MCU as a control unit that controls and works to give water to the plants, by using soil moisture sensor, when the soil moisture is not sufficient according to the specifications that have been set, then the water from the DC pump will open to flow water to the plants. Next DHT 11 sensors will work to detect temperature & humidity, if the weather temperature exceeds 35.20°C, and then water will be given. In addition, each measured data will be displayed on the LCD and in telegram.

Project Results

1. Automatic Watering Based on Plant Needs: The system will detect soil moisture levels and activate the pump only when necessary, preventing overwatering or underwatering.

2. Optimized Water Usage: Water will be used efficiently, reducing waste and conserving resources through intelligent sensor-based control.

3. Remote Monitoring via Telegram: Users will receive real-time notifications of temperature, humidity, and soil moisture status through the Telegram app.

4. Healthy Plant Growth: Consistent and timely watering will maintain optimal soil moisture conditions, promoting better plant health and growth.

5. Reduced Manual Effort: The automated system will save time and labor by eliminating the need for manual watering.

6. Integration of Smart Sensors: The use of DHT11 and soil moisture sensors will ensure accurate environmental monitoring.

7. Demonstration of Smart Agriculture Technology: The project will serve as a model for applying IoT and automation in indoor gardening, supporting sustainability.

V. ELECTRICAL/ELECTRONIC CIRCUIT CONNECTION

The Automated Watering Plant System uses the Arduino Uno, a basic microcontroller board without Wi-Fi capability, making it suitable for offline and standalone operations. In contrast, the Indoor Gardening Irrigation System is powered by the ESP8266 NodeMCU, which has built-in Wi-Fi, allowing it to connect to the internet and interact with cloud services for remote monitoring and control. Sensor-wise, the Automated Watering Plant System does not include a DHT22 sensor, which is typically used for temperature and humidity measurements. Simultaneously, temperature and humidity readings are displayed on the LCD and transmitted to the connected mobile application via Wi-Fi. The system then loops back to continuous monitoring mode. This cyclic process ensures real-time decision-making, efficient water usage, and autonomous irrigation control without manual intervention.

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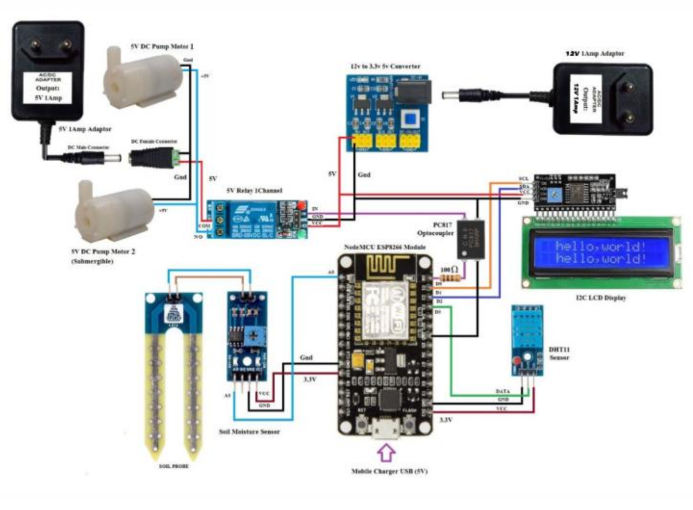

Figure 1: Proposed design

On the other hand, the Indoor Gardening Irrigation System utilizes a DHT11 sensor, a simpler and cost-effective alternative to the DHT22, to collect environmental data like temperature and humidity. Regarding output display, the Automated Watering Plant System only relies on an LCD to show sensor values locally. In comparison, the Indoor Gardening Irrigation System displays information via both LCD and Telegram, leveraging the internet connectivity of the ESP8266 for remote monitoring capabilities.

VI. BLOCK DIAGRAM

The proposed Indoor Gardening Irrigation System is designed as an IoT-enabled, sensor-driven automated watering framework that integrates environmental monitoring, intelligent decision-making, and remote communication. The core of the system is the ESP8266 NodeMCU microcontroller, selected for its low power consumption, built-in Wi-Fi capability, and suitability for embedded IoT applications. The hardware architecture consists of a soil moisture sensor for measuring soil water content, a DHT11 sensor for monitoring ambient temperature and relative humidity, a relay module for pump control, a water pump connected through a pipeline distribution network, and an LCD module for real-time local display.

The system operates on a closed-loop control mechanism. Sensor data are continuously acquired and processed by the microcontroller. Predefined threshold values corresponding to plant-specific moisture requirements are programmed into the controller. When soil moisture falls below the lower threshold limit, the relay module activates the water pump to supply water through the connected piping system. Once the moisture level reaches the predefined optimal range, the pump is automatically turned off. Additionally, environmental data collected from the DHT11 sensor provide contextual insight into atmospheric conditions, which can influence irrigation frequency. The integrated Wi-Fi module enables remote monitoring and notification services through platforms such as Telegram, ensuring real-time user interaction and supervision. The overall design emphasizes modularity, scalability, water conservation, and energy efficiency.

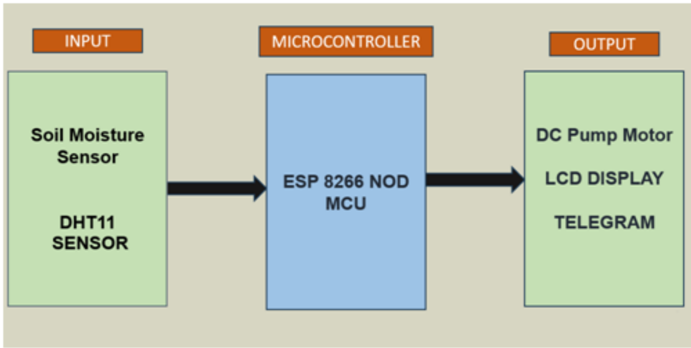

Figure 2: Proposed block diagram

This diagram illustrates a basic automated irrigation system that utilizes sensors and a microcontroller. Input Section Soil Moisture Sensor (DHT11 Sensor): This sensor measures the moisture level in the soil. It helps in determining whether the soil is dry or adequately moist for plant growth. Microcontroller Section ESP 8266 NOD MCU: This is the microcontroller unit that processes the information received from the soil moisture sensor.

3D Design of Proposed System

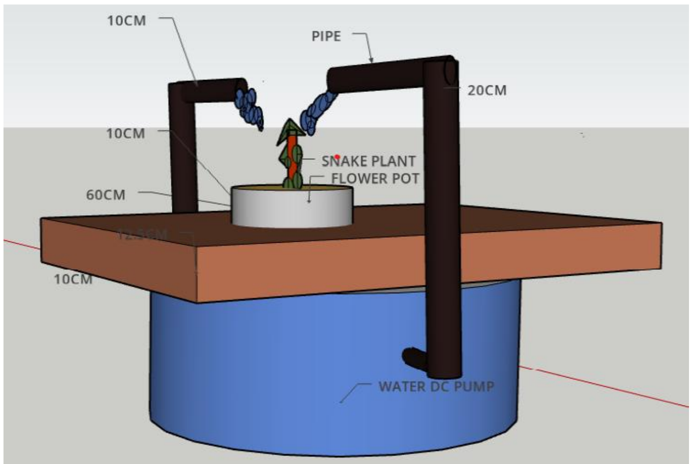

Figure 3: 3D Design of Proposed System

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It is capable of controlling other components based on the data it processes. Output Section DC Pump Motor: This component is activated to water the plants when the soil moisture levels are low. LCD Display: This display shows real-time data about soil moisture levels, providing visual feedback to the user. Telegram: This indicates that the system can communicate with a messaging platform (like Telegram) to send notifications or alerts regarding the soil moisture status. This automated system helps in efficient irrigation management, ensuring plants receive the right amount of water based on soil conditions.

Flowchart

The system workflow begins with power initialization and configuration of input-output peripherals of the ESP8266 NodeMCU. After initialization, the microcontroller continuously reads data from the soil moisture sensor and DHT11 sensor. The acquired soil moisture value is compared with predefined threshold limits stored in the program memory.

If the measured moisture value is above the minimum threshold, the irrigation pump remains in the OFF state, and the system continues monitoring. If the moisture value drops below the specified lower limit, the controller activates the relay module, turning the water pump ON to initiate irrigation. During watering, the soil moisture is continuously monitored in real time. Once the moisture level reaches the optimal upper threshold value, the pump is turned OFF automatically.

Simultaneously, temperature and humidity readings are displayed on the LCD and transmitted to the connected mobile application via Wi-Fi. The system then loops back to continuous monitoring mode. This cyclic process ensures real-time decision-making, efficient water usage, and autonomous irrigation control without manual intervention.

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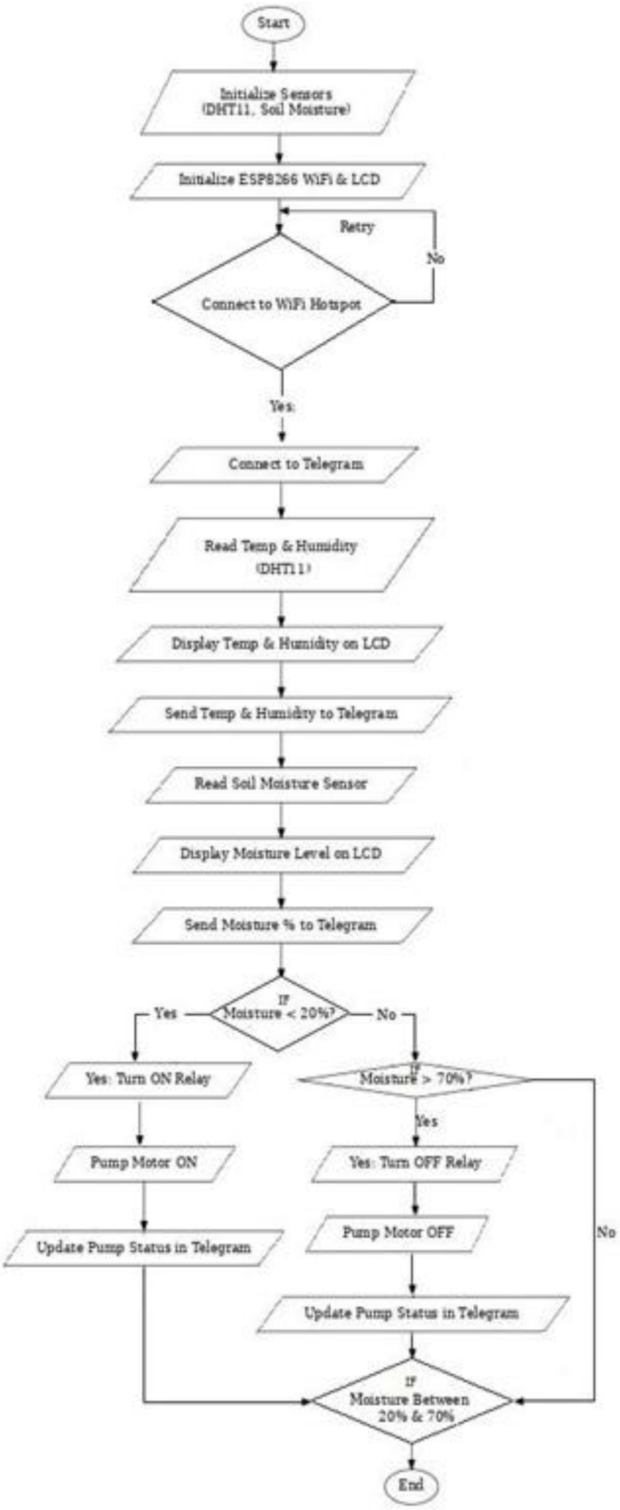

Figure 4: Flow chart

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VII. RESULTS ANALYSIS

The experimental implementation of the proposed system demonstrated reliable and efficient irrigation control under varying environmental conditions. Soil moisture levels were successfully maintained within predefined optimal ranges, preventing both overwatering and underwatering scenarios. The automated pump control mechanism responded accurately to threshold-based conditions, ensuring timely irrigation with minimal latency.

The integration of IoT communication enabled real-time data transmission and monitoring via a mobile platform, improving system transparency and user accessibility. Environmental data from the DHT11 sensor provided valuable insight into temperature and humidity variations, which can influence irrigation scheduling. Power consumption remained within acceptable limits due to the low-energy characteristics of the ESP8266 module.

Water usage analysis indicated a significant reduction in unnecessary water discharge compared to manual watering practices. The system maintained consistent performance over extended operation periods, confirming its stability and reliability. Minor network delays were observed during peak connectivity fluctuations; however, they did not affect the core irrigation functionality, as the decision-making process operates locally within the microcontroller. Overall, the results validate that the proposed system enhances irrigation precision, conserves water resources, and reduces human effort in indoor gardening environments.

When the soil moisture is dry, the pump motor automatically turns ON.

When the soil moisture reaches a sufficient level (e.g., 89%), the pump motor turns OFF.

The system sends real-time updates to the Telegram app, showing Temperature, Humidity, Soil Moisture status.

VIII. CONCLUSION

The “Indoor Gardening Irrigation System” is an innovative solution designed to automate plant watering using IoT technology. By integrating sensors, a microcontroller, and a mobile application, the system ensures optimal moisture levels for indoor plants while reducing water waste and manual effort. The project successfully demonstrates how automation can simplify plant care, making it more efficient and reliable.

One of the key achievements of this system is its ability to monitor soil moisture in real-time using a soil moisture sensor. When the moisture level drops below a set threshold, the system activates a DC water pump to irrigate the plants, stopping once the soil reaches the desired moisture level. This prevents both underwatering and overwatering, promoting healthier plant growth. Additionally, the inclusion of a DHT11 sensor allows the system to track temperature and humidity, providing users with a complete environmental overview.

The use of the ESP8266 NodeMCU microcontroller enables IoT connectivity, allowing the system to send real-time data and alerts to users via the Telegram app. This remote monitoring feature ensures that users can check plant conditions and system status from anywhere, enhancing convenience and responsiveness. The system also includes an LCD display for local feedback, making it accessible even without an internet connection.

From a practical standpoint, the project’s modular design, featuring PVC pipes for water delivery and an enclosure for electronics, ensures durability and ease of maintenance. The system is scalable and can be adapted for larger setups or different plant types with minimal modifications. In conclusion, the “Indoor Gardening Irrigation System” effectively addresses common challenges in plant care by combining automation, IoT, and smart monitoring. It offers a reliable, water-efficient, and user-friendly solution for indoor gardening, making it a valuable tool for both hobbyists and small-scale agricultural applications. The project not only meets its objectives but also lays the groundwork for further advancements in smart irrigation technology.

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