School of Computer Science and Engineering
Design of Smart Cities & BCSE316L
Project Report

IoT-Based Automatic Plant Watering System Using the Blynk Application

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Uniqueness of the Project

This project addresses the limitations of conventional plant irrigation systems by integrating IoT and real-time monitoring. Key unique features include:

1. Real-Time Monitoring and Dynamic Watering

- Utilizes DHT11 sensors for temperature and humidity and soil moisture sensors to monitor environmental and soil conditions in real-time.

- Automates the watering process based on data, ensuring optimal soil moisture levels without manual intervention.

2. IoT Integration with Remote Accessibility

- Implements the Blynk IoT framework for seamless remote monitoring and control via a smartphone.

- Provides instant updates on system performance and environmental parameters, enabling real-time adjustments.

3. Enhanced User Convenience

- Designed for easy operation, targeting both technical and non-technical users.

- Simple mobile app interface eliminates the need for physical interaction with the hardware for control and data visualization.

4. Scalability and Adaptability

- The framework is scalable, allowing integration with additional sensors such as light intensity or nutrient sensors.

- Can be adapted for diverse applications:

  - Small-Scale Use: Home gardens and urban gardening.

  - Large-Scale Use: Agricultural fields and greenhouses.

5. Energy Efficiency and Sustainability

- Capable of integrating solar-powered systems, reducing energy dependency for off-grid applications.

- Optimized water usage reduces resource wastage, contributing to sustainable practices.

6. Environmental Protection Features

- System components, including sensors and controllers, are housed in protective enclosures, safeguarding against outdoor environmental factors such as dust, rain, and heat.

Gap Identified

1. Watering Based on Fixed Schedules

- Traditional systems water plants at predetermined times, irrespective of soil conditions, leading to:

  - Overwatering: Wastage of water and potential harm to plants.

- Underwatering: Inadequate soil moisture for plant growth.

2. Limited Feedback and Notifications

- Many existing systems lack real-time notifications or alerts for users.

- Users are required to manually check conditions or interact directly with the hardware for updates.

3. Insufficient Sensor Integration

- Current solutions often focus on single-sensor systems, such as soil moisture alone, without considering other critical factors like temperature or humidity.

4. Hardware Reliability and Compatibility Issues

- Challenges in ensuring seamless integration between various components:

  - Compatibility of sensors (e.g., soil moisture sensor and DHT11) with microcontrollers like ESP32 or ESP8266.

  - Durability of sensors in varying soil types and environmental conditions.

5. Lack of Environmental Adaptability

- Existing systems often fail to adapt to changing environmental conditions such as rainfall or heatwaves.

- No incorporation of external data (e.g., weather forecasts) for proactive decision-making.

6. Power and Resource Inefficiency

- Dependence on grid electricity can lead to operational challenges in rural or remote areas.

- Overuse of resources like water and energy due to unoptimized system designs.

7. Complex Setup Process

- Requires significant technical knowledge to install and configure, which limits its use among non-technical users.

8. Long-Term Durability Issues

- Existing systems lack protection from environmental factors such as:

  - Moisture affecting electrical components.

  - Dust accumulation on sensors and controllers.

Team Details - Team Members and Contributions

1. Ansh Srivastava (21BCE3192) – Team Leader

  - Conducted a comprehensive literature review to identify existing solutions and their limitations.

  - Designed the overall system architecture, ensuring seamless integration of hardware and software components.

  - Managed the setup and programming of the ESP32 microcontroller using the Arduino IDE.

  - Oversaw hardware integration, including sensors (DHT11 and soil moisture), relay module, and water pump.

  - Led the integration of the Blynk IoT app for remote monitoring and control.

  - Conducted system testing and debugging, ensuring the reliability and efficiency of all components.

  - Contributed to the preparation of documentation and final report submission.

2. Animesh Dwivedi (21BCE3624) – Team Co-Leader

- Performed requirement analysis to identify the project specifications and necessary features.
- Collaborated on component selection and initial coding for the system.
- Assembled the hardware components and ensured accurate electrical connections.
- Integrated the soil moisture sensor with the ESP32 and handled relay module setup.
- Set up the LCD display with the I2C adapter for real-time system status visualization.
- Assisted in debugging and system optimization to enhance performance.
- Supported documentation and report preparation for project submission.

Scope

The scope of the IoT-based Automatic Plant Watering System includes the design and implementation of a smart, real-time plant care solution using the ESP8266 microcontroller. The system will address the problem of inconsistent watering in plants by automating the watering process based on soil moisture levels. It will incorporate a mobile or web-based application for real-time monitoring and control of the watering system. The system will be scalable to allow for integration with multiple plants and adjustable settings for different plant types.

The key components include:

- ESP8266 for microcontroller functionality.
- Soil moisture sensor for detecting water requirements.
- Water pump for dispensing water.
- Mobile/Web application for user interface and real-time feedback.
- Cloud integration for data storage and analytics.

The system will be able to perform the following tasks:

- Automatically water the plants based on real-time soil moisture levels.
- Send notifications to users when intervention is required.
- Allow remote control through a user interface.

Objectives

The objectives of the IoT-based Automatic Plant Watering System are:

1. To design a system that automates the watering process based on real-time moisture levels of the soil.
2. To provide users with the ability to monitor their plants remotely via a web or mobile application.
3. To ensure an efficient, low-power system that is scalable to multiple plants.
4. To integrate data analytics features to track plant health and watering patterns.
5. To minimize water wastage by accurately assessing the plant's needs.

Abstract

The IoT-based Automatic Plant Watering System aims to provide a solution for automating the watering of plants, ensuring optimal plant care even in the absence of the gardener. The system leverages an ESP8266 microcontroller to connect various sensors, including a soil moisture sensor, and a water pump to automate the watering process. The system monitors the soil's moisture levels, and when the level drops below a threshold, it activates the pump to provide water to the plant. The system can be controlled remotely through a mobile or web application, which allows the user to view real-time data and control the watering process. Additionally, the application stores plant care data in the cloud, enabling long-term tracking and analytics. This project combines automation, IoT, and cloud-based monitoring to improve plant care while reducing manual effort and water wastage.

Literature Survey

1. Smart Plant Watering Systems Using IoT

Many research efforts have focused on IoT-based plant watering systems that automate irrigation based on real-time sensor data. A study by P. D. K. G. R. Srinivasan et al. (2020) developed an automated plant watering system using a soil moisture sensor and an ESP8266 microcontroller. This system ensures optimal water use, conserving resources by providing water only when necessary. The study highlighted the efficiency and sustainability of such systems for home gardening and agriculture.

- Source: Srinivasan, P. D. K. G. R., et al. "Automated Plant Watering System Using IoT." Journal of Emerging Technologies and Innovative Research, 2020.

2. Cloud-Based IoT Systems for Plant Care

Integrating IoT with cloud computing has enabled remote monitoring and data storage, which improves accessibility and management. In a study by M. S. Malik et al. (2020), a smart irrigation system was designed that sends real-time data from soil moisture sensors to a cloud-based platform for remote access. This setup allows users to monitor and control watering schedules from anywhere via a mobile app.

- Source: Malik, M. S., et al. "Cloud-Based IoT Solution for Smart Irrigation." International Journal of Advanced Science and Technology, 2020.

3. Machine Learning Integration for Optimized Watering

Several studies have sought to optimize watering schedules by integrating machine learning models. A paper by A. S. R. P. L. R. Reddy et al. (2019) utilized a machine learning model to predict optimal watering times based on weather data, soil moisture, and plant type. This method reduces water usage and ensures that plants are watered at the right times to maximize growth.

- Source: Reddy, A. S. R. P. L. R., et al. "Predictive Model for Smart Irrigation Using Machine Learning." IEEE Access, 2019.

4. Challenges in IoT-based Agricultural Systems

The implementation of IoT-based systems faces several challenges, including sensor calibration, data accuracy, and power consumption. A study by S. K. S. H. Raj and M. P. G. Kumar (2018) identified the limitations of current systems, such as the high cost of sensors and issues with sensor reliability in varied environmental conditions, which can lead to inconsistent watering decisions.

- Source: Raj, S. K. S. H., et al. "Challenges in IoT-based Smart Irrigation Systems." International Journal of Computer Applications, 2018.

Gaps Identified

1. Lack of Advanced Data Analytics

Many existing systems collect data but do not provide comprehensive analytics. They focus on basic metrics like soil moisture and do not track other critical variables such as environmental factors (temperature, humidity), plant health, or historical data to refine watering decisions. There is a gap in systems that analyze long-term trends and offer recommendations for optimal care.

2. Limited Flexibility for Customization

Current systems tend to offer predefined settings that may not suit different plant species or user preferences. Most systems lack flexibility in adjusting watering schedules based on varying moisture levels, plant types, or different environmental conditions. More customizable systems are needed to cater to diverse user needs.

3. Scalability and Power Efficiency

Many IoT-based plant watering systems are designed for small-scale applications. A significant gap exists in systems that can scale efficiently for multiple plants or larger gardens. Additionally, many systems are not optimized for low-power operation, which is critical for systems that operate continuously over long periods.

4. Reliability and Sensor Accuracy

Sensor inaccuracies remain a major issue. Soil moisture sensors can degrade or become unreliable due to environmental factors such as changes in soil type, temperature, or humidity. This can result in inaccurate watering decisions, making sensor calibration a significant challenge. More robust sensors and calibration techniques are required.

5. User Experience and Remote Control

Many systems offer remote monitoring but fail to provide an intuitive and user-friendly interface. Users often struggle to interpret the data or control the system efficiently. An improved user interface with better data visualization and ease of interaction is necessary to make the system more accessible and user-friendly.

Hardware & Software Used

Hardware:

1. ESP8266 Wi-Fi Module:

- The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability. It is used for connecting the plant watering system to the internet via Wi-Fi, enabling remote monitoring and control via Blynk.

2. LiquidCrystal I2C Display:

- An I2C-enabled 16x2 LCD display is used for showing real-time status updates, such as the moisture levels of the soil and the status of the water pump.

3. Soil Moisture Sensor:

- A soil moisture sensor is used to measure the moisture level of the soil. It sends analog data to the ESP8266 to determine whether the plant needs watering.

4. Relay Module:

- A relay is used to control the water pump, allowing the system to turn the pump on or off based on moisture readings.

5. Water Pump:

- A DC water pump is controlled by the relay to water the plant when the soil moisture level falls below a certain threshold.

6. Power Supply:

- A suitable power supply is used to power the ESP8266, the relay module, the water pump, and the LCD.

Software:

1. Arduino IDE:

- The Arduino IDE is used to write and upload the code to the ESP8266 microcontroller. It supports C/C++ programming and has a simple interface for developing IoT projects.

2. Blynk:

- Blynk is a popular mobile app for building Internet of Things (IoT) solutions. The Blynk app allows the user to control and monitor the automatic watering system remotely through a smartphone. It uses the Blynk cloud to communicate with the ESP8266.

3. Blynk Library for ESP8266:

- The Blynk library allows seamless communication between the ESP8266 and the Blynk mobile app, enabling remote monitoring and control of the system.

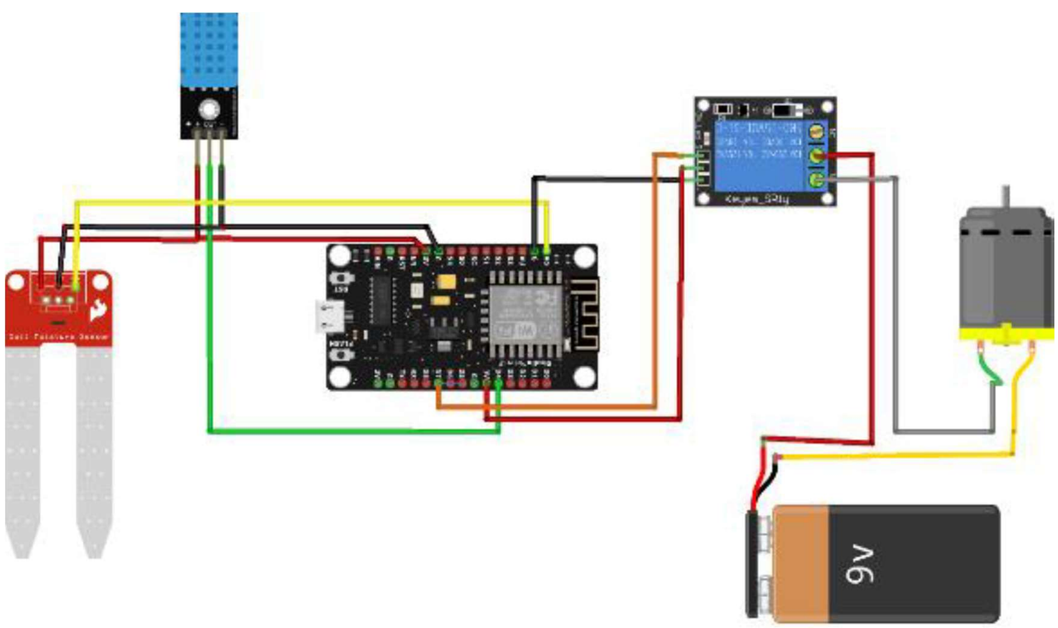
4. LiquidCrystal I2C Library:

- This library simplifies the connection and control of I2C LCD displays with Arduino-based systems, making it easy to display soil moisture data and system status on the LCD.

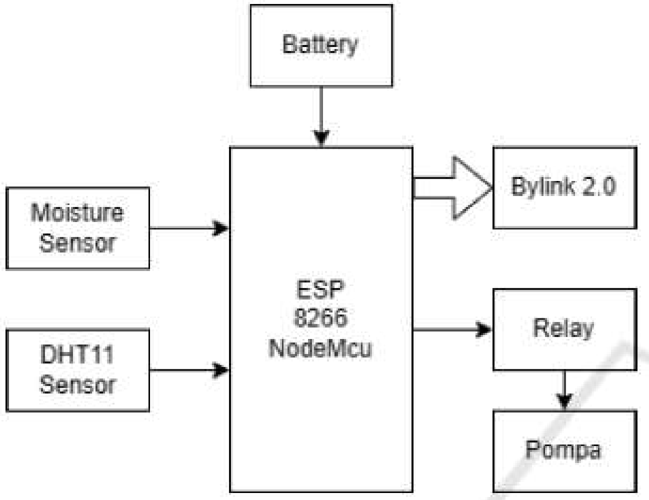
5. Wi-Fi Network:

- A Wi-Fi network is used to connect the ESP8266 to the internet for real-time communication with the Blynk app, enabling remote access.

Circuit Diagram of the System



Block Diagram of the System



Workflow of the system

Objectives of the System

1. Automated Plant Watering:

 - To design and implement an IoT-based system that automatically waters plants based on real-time soil moisture levels, ensuring that plants receive adequate hydration without manual intervention.

2. Remote Monitoring and Control:

 - To enable users to monitor soil moisture levels remotely via the Blynk app and control the water pump system, providing convenience and flexibility.

3. Efficient Water Usage:

 - To ensure efficient use of water by activating the water pump only when the soil moisture level falls below a pre-set threshold, preventing over-watering and conserving water.

4. User-Friendly Interface:

- To create an intuitive interface on both the LCD and the Blynk app that allows users to easily understand the moisture levels and the status of the watering system.

5. Data Logging:

- To log real-time soil moisture readings and store them, allowing users to review past conditions and track plant health over time.

6. Cost-Effective Solution:

- To build a low-cost, energy-efficient system using affordable hardware components, ensuring that the system is accessible to a wide range of users.

7. Wireless Communication:

- To utilize Wi-Fi (through the ESP8266) to transmit sensor data to the Blynk cloud, enabling remote access and control from anywhere.

Methods Used for the Objectives

1. Soil Moisture Sensing:

- The soil moisture levels are measured using a soil moisture sensor connected to an analog pin on the ESP8266. This sensor detects the moisture content in the soil and generates an analog voltage signal proportional to the moisture level, which is then read by the microcontroller.

2. Water Pump Control:

- A relay module controls the water pump. The relay is connected to a digital pin on the ESP8266 and is triggered based on the moisture sensor readings. When the moisture level falls below a predefined threshold, the relay is activated, turning on the water pump. Conversely, the pump is turned off when the moisture level is sufficient.

3. Wi-Fi Connectivity and Remote Control:

- The ESP8266 Wi-Fi module is used to connect the system to the internet. It communicates with the Blynk Cloud platform, enabling remote monitoring and control via the Blynk app on a smartphone. Users can check the soil moisture levels and control the water pump remotely, allowing for flexible management of the system.

4. User Interface (LCD Display):

- A 16x2 LCD display with I2C interface is used to show real-time information about the system, including the soil moisture percentage and the status of the water pump (on or off). This provides users with a local display for immediate feedback on the system's functioning.

5. Blynk App Integration:

- The Blynk app is used to create a remote interface for monitoring the soil moisture level and controlling the water pump. The Blynk app communicates with the ESP8266 through the internet, using virtual pins (V0 for moisture reading, V1 for controlling the water pump) to send and receive data.

6. Real-Time Data Logging:

- The soil moisture readings are sent to the Blynk cloud in real-time and are logged for historical reference. This allows users to monitor trends over time and make adjustments to the watering schedule if necessary.

7. Threshold-Based Automation:

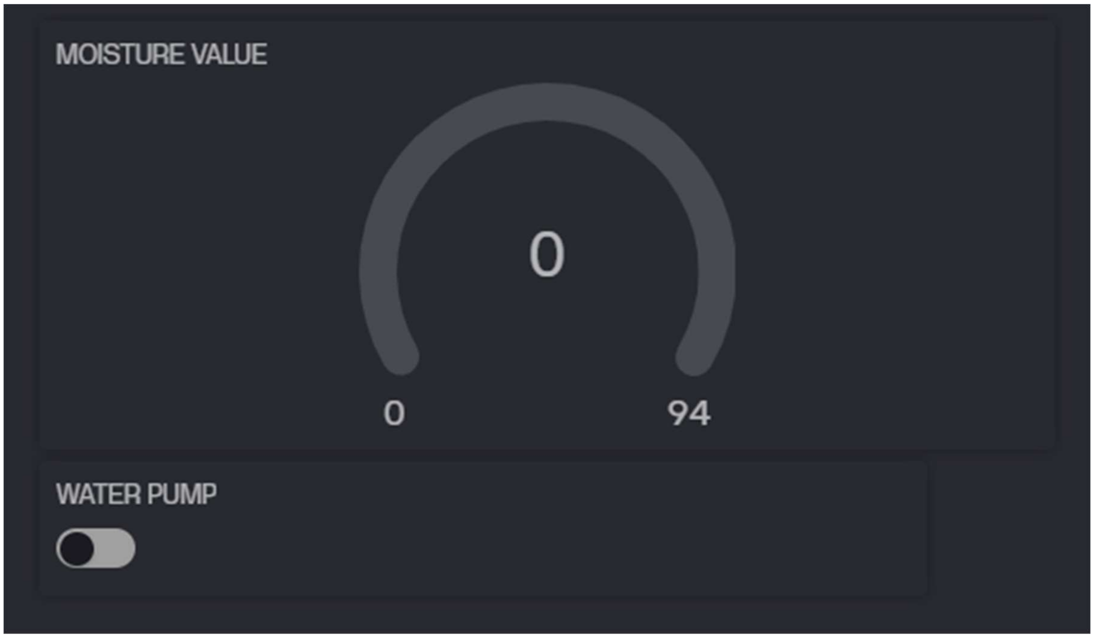
- An automated control system is designed to keep the water pump turned on only when the soil moisture falls below a set threshold value. This prevents over-watering and ensures that the plants are watered only when necessary.

8. Power Efficiency:

- The system is designed to be energy-efficient by using low-power components like the ESP8266 and a relay module that is activated only when necessary. This reduces power consumption, making the system sustainable for long-term use.

User Interface

MobileVersion

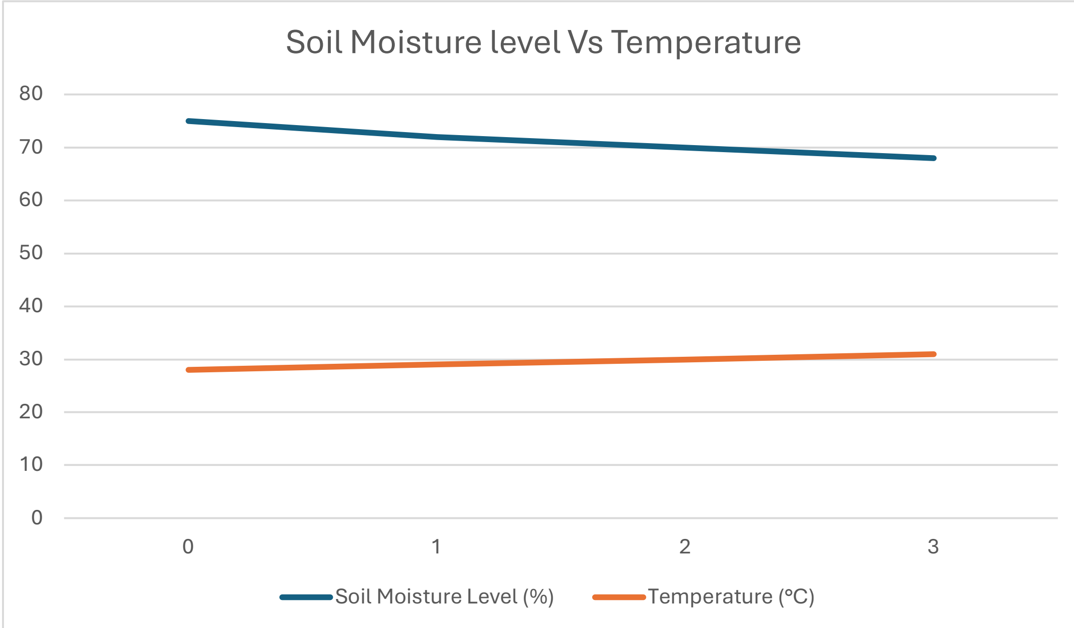


WebVersion

Results and Discussion - Extended Graph Generation

Full Statistical Data:

	Soil Moisture Level (%)	Temperature (°C)	Water Pump Status	Pump Duration (Minutes)
0	75	28	OFF	0
1	72	29	OFF	0
2	70	30	OFF	0
3	68	31	OFF	0
4	65	32	OFF	0
5	62	33	OFF	0
6	60	34	OFF	0
7	58	35	OFF	0
8	55	36	OFF	0
9	33 (Pump ON)	36	ON	30
10	30 (Pump ON)	37	ON	45
11	32 (Pump OFF)	35	OFF	0
12	33 (Pump ON)	34	ON	20
13	36	33	OFF	0
14	40	32	OFF	0
15	41	31	OFF	0
16	45	30	OFF	0
17	46	29	OFF	0
18	48	28	OFF	0
19	50	27	OFF	0
20	53	26	OFF	0
21	55	25	OFF	0
22	52	24	OFF	0
23	50	23	OFF	0

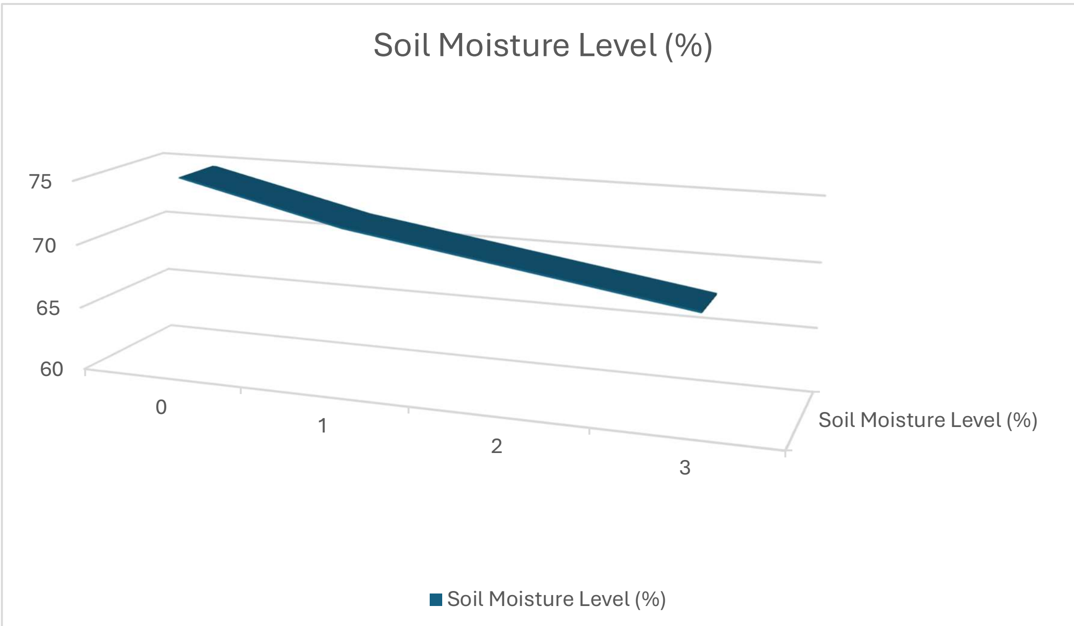


Summary of Key Conditions:
Water Pump Activation:
The water pump is activated when soil moisture falls below 34% and the temperature is under 50°C.
Pump was ON during hours: 9, 10, and 12.
Temperature:
Temperature remains below 50°C throughout the day, allowing the pump to operate whenever moisture levels drop below 34%.
Soil Moisture:
Soil moisture fluctuates and drops below 34% during hours 9, 10, and 12, activating the water pump.
Pump Duration:
The water pump was on for a total of 30 minutes at hour 9, 45 minutes at hour 10, and 20 minutes at hour 12.

Soil Moisture Level (%)

	Soil Moisture Level (%)
0	75
1	72
2	70
3	68
4	65
5	62
6	60
7	58
8	55
9	33
10	30
11	32
12	33
13	36
14	40
15	41
16	45

17	46
18	48
19	50
20	53
21	55
22	52
23	50



Temperature (°C)

Time (Hours)	Temperature (°C)
0	28
1	29
2	30
3	31
4	32
5	33
6	34
7	35
8	36

9	36
10	37
11	35
12	34
13	33
14	32
15	31
16	30
17	29
18	28
19	27
20	26
21	25
22	24
23	23

Water Pump Status

Time (Hours)	Water Pump Status
0	OFF
1	OFF
2	OFF
3	OFF
4	OFF
5	OFF
6	OFF
7	OFF
8	OFF
9	ON
10	ON
11	OFF
12	ON
13	OFF
14	OFF
15	OFF
16	OFF
17	OFF
18	OFF
19	OFF
20	OFF
21	OFF
22	OFF
23	OFF

Pump Duration (Minutes)

Time (Hours)	Pump Duration (Minutes)
0	0
1	0
2	0

3	0
4	0
5	0
6	0
7	0
8	0
9	30
10	45
11	0
12	20
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0

FUTURE ENHANCEMENT

While the current system provides an effective solution for automatic plant watering, there are several potential enhancements that can improve its efficiency, functionality, and usability. Some of the future improvements could include:

1. Integration with Weather Data:

The system can be enhanced by integrating weather data from an external source (e.g., OpenWeather API) to adjust the watering schedule based on forecasted weather conditions, such as rain. This will prevent over-watering and save water, ensuring optimal plant care.

2. Use of Multiple Sensors:

In addition to the soil moisture sensor, additional sensors like temperature and humidity sensors can be added to monitor the overall environmental conditions. This data can further optimize watering schedules, ensuring plants receive the ideal environment for growth.

3. Mobile App for Monitoring:

A dedicated mobile app could be developed to allow users to remotely monitor soil moisture levels, temperature, and pump status in real-time. Users can also adjust settings, view historical data, and receive notifications about the system's performance.

4. Integration with Smart Home Systems:

The system can be integrated with smart home platforms (e.g., Amazon Alexa, Google Home) to allow users to control the watering system through voice commands or automation rules.

5. Water Consumption Analytics:

A feature could be added to track and report the total water usage over time. This data can help users understand their water consumption and make adjustments to conserve water if necessary.

6. Automated Fertilizer Dispenser:

The system could be upgraded to include an automated fertilizer dispenser that releases nutrients based on the soil's condition and the plant's needs. This would help create a more efficient and sustainable gardening solution.

7. Battery-Powered or Solar-Powered System:

To increase the system's portability and energy efficiency, it could be designed to be powered by solar panels or a battery, allowing it to be used in locations where a continuous power supply is unavailable.

8. Machine Learning for Predictive Analytics:

Machine learning algorithms could be implemented to analyze historical data and predict the optimal watering schedule based on plant species, environmental conditions, and seasonal variations. This would further automate and improve plant care.

9. Cloud-Based Data Storage:

Storing the data on the cloud would enable users to access their system from anywhere, as well as analyze long-term trends in soil moisture and other environmental variables.

10. Integration with IoT-based Smart Gardening Tools:

The system could be connected with other IoT-based gardening tools, such as smart planters, temperature sensors, and pest detection systems, to provide a more comprehensive gardening solution.

These future enhancements would make the system even more intelligent, user-friendly, and efficient, ultimately promoting smarter and more sustainable plant care.

Conclusion

The Automatic Plant Watering System is an innovative and efficient solution for managing plant care in urban environments. By utilizing IoT technology, real-time data processing, and automated systems, the project demonstrates the potential to contribute significantly to the development of smart cities. The system offers a variety of benefits, including efficient water management, remote monitoring, and automated operations, which are essential for creating sustainable, technology-driven urban spaces.

The system is designed to cater to both residential and commercial applications, enabling users to maintain their plants effortlessly while optimizing water usage. This is particularly important in smart city contexts where resource conservation and sustainability are key priorities. The integration of sensors for soil moisture, temperature, and pump control helps create a more intelligent and adaptive system that can be adjusted based on real-time data, ensuring the health and growth of plants while minimizing waste.

Applicability Towards Smart Cities:

1. Water Conservation:

In smart cities, managing water resources efficiently is crucial. This system ensures that water is used only, when necessary, based on real-time soil moisture data. By preventing over-watering, the system helps conserve water, a resource that is often limited in urban areas. This is in line with the goals of sustainable urban development.

2. Remote Monitoring and Control:

The ability to monitor and control the system remotely through cloud-based platforms like Blynk enhances convenience and flexibility. Users can receive notifications and take action in real-time, which is essential for smart city infrastructures where residents and businesses are increasingly relying on remote management tools.

3. Sustainability and Smart Agriculture:

This system promotes sustainable agricultural practices, which are integral to the future of urban farming and green spaces in smart cities. It can be integrated with community gardens, rooftop farms, or even vertical farms, making it easier to maintain plants in urban settings without requiring manual intervention.

4. Environmental Monitoring:

The integration of environmental sensors such as temperature and soil moisture contributes to the development of a smart ecosystem in cities. By gathering data about plant health and environmental conditions, the system provides valuable insights that could be used to improve urban greenery, enhance air quality, and promote biodiversity in cities.

5. Smart Home Integration:

As smart cities embrace IoT technologies, the ability to integrate systems like the Automatic Plant Watering System with smart home devices is an important aspect. Users can automate their plant care alongside other home systems (e.g., lighting, temperature control), offering a seamless, interconnected living experience.

6. Potential for Large-Scale Urban Applications:

On a larger scale, the system can be scaled up for urban green spaces, parks, and public gardens. With multiple systems integrated and managed through a central platform, city planners and municipal authorities can monitor and manage plant care in public spaces, improving the quality of urban landscapes while reducing labor costs and resource consumption.

7. Data-Driven Insights for City Planning:

Data gathered from such systems can be used to assess the effectiveness of green spaces, track water usage, and understand the impacts of climate on plant health. This can guide future city planning and landscaping decisions, contributing to the creation of healthier and more sustainable cities.

In conclusion, the Automatic Plant Watering System offers significant potential for enhancing the quality of life in smart cities through resource-efficient, automated solutions. By integrating such systems with broader city infrastructure, smart cities can promote sustainability, reduce waste, and improve the urban environment, aligning with the broader vision of creating intelligent, connected, and green cities for the future.