International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 8, Issue 3, pp 332-339, March-2024

https://doi.org/10.47001/IRJIET/2024.803051

IoT Based Smart Agriculture / Gardening

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***Abstract* - Traditional agriculture rely heavily on manual monitoring and irrigation, leading to water waste, uneven crop growth, and increased labor costs. This paper proposes an Internet of Things (IoT)-based smart agriculture system for optimized irrigation. The system uses an ESP32 microcontroller to collect soil moisture data from sensors. User-defined thresholds trigger automated watering using a relay-controlled mechanism. The system offers on-site monitoring through an OLED display and remote monitoring capabilities via the Blynk platform. This paper details the system design, implementation, and testing, demonstrating its power for efficient water use and improved crop yield in agricultural and gardening applications.**

Keywords: IoT, Smart Agriculture, ESP32, Soil Moisture Sensor, Irrigation Automation, Remote Monitoring.

I. INTRODUCTION

1.1 The Evolving Landscape of Agriculture

The global agricultural landscape undergoes a significant transformation. While traditional practices have served humanity well for centuries, a growing population and a changing climate necessitate a paradigm shift. The Food and Agriculture Organization (FAO) projects a 70% increase in food production by 2050 to feed a projected 9.7 billion people [1]. However, this demand for increased output coincides with dwindling water resources and heightened environmental concerns. Climate change disrupts weather patterns, leading to more frequent droughts in some regions and excessive rainfall in others. Traditional irrigation practices, often reliant on manual monitoring and rule-of-thumb decisions, contribute to water waste, uneven crop growth, and increased labor costs.

1.2 The Rise of IoT in Agriculture

The Internet of Things (IoT) emerges as a transformative force in agriculture, enabling data-driven and automated solutions to these challenges. IoT refers to a network of physical devices embedded with sensors, software, and other technologies that collect and exchange data. By integrating sensors, microcontrollers, and cloud platforms, IoT-based smart agriculture systems revolutionize agricultural practices [2]. These systems can monitor various environmental parameters like soil moisture, temperature, humidity, and light intensity, providing valuable insights into crop health and growth conditions. Furthermore, they can automate tasks like irrigation, nutrient delivery, and pest control based on real-time sensor data and user-defined thresholds. This precise and data-driven approach promotes efficient resource management, reduces water waste, and optimizes crop yields.

1.3 Existing Research and Inspiration

Several researchers have delved into the potential of IoT in agriculture, demonstrating its effectiveness in various applications. Al-Fuqahaa et al. [3] propose an IoT-based smart irrigation system that utilizes soil moisture sensors and a cloud platform to automate irrigation based on real-time data. Their research highlights a significant reduction in water usage compared to traditional methods. Similarly, Pandeti et al. [4] present a smart agriculture system using wireless sensor networks to monitor environmental parameters and control irrigation systems. Their system incorporates machine learning algorithms to analyze sensor data and predict crop health, enabling proactive interventions. These studies, along with numerous others, inspire our exploration of IoT's potential to enhance agricultural practices.

1.4 Our Contribution and Research Focus

This paper presents the design, implementation, and evaluation of an IoT-based smart agriculture/gardening system aimed at addressing water waste and inefficient resource management in traditional practices. Our system builds upon existing research by emphasizing user-friendliness and ease of implementation, making it adaptable to both small-scale gardening applications and larger agricultural settings. The primary objectives of our research are as follows:

- Design and develop an IoT-based smart agriculture system using readily available and cost-effective components.
- Implement sensor technology for real-time data collection on soil moisture, temperature, and humidity.

- Develop an automated irrigation system controlled by user-defined thresholds for optimal water management.
- Provide options for on-site monitoring through an OLED display and remote monitoring capabilities through a cloud platform.
- Evaluate the effectiveness of the system in promoting efficient water use and improving potential crop yield.

1.5 Significance and Impact

By exploring the potential of readily available technology, this project aims to contribute to the development of more sustainable and productive agricultural practices. The proposed system offers a user-friendly and cost-effective solution for both hobbyists and professional growers, allowing them to optimize irrigation strategies and improve resource management. Furthermore, the data collected by the system can be analyzed to identify trends and patterns in plant growth, providing valuable insights for further research and development in precision agriculture. In conclusion, this research project presents a practical and innovative approach to utilizing IoT technology to address the challenges of water scarcity and resource management in agriculture, paving the way for a more sustainable and efficient future for food production.

II. LITERATURE SURVEY

2.1) Integration of IoT in Agricultural Practices: A Review. Smith, J., et al. (2020). Journal of Agricultural Engineering.

The integration of Internet of Things (IoT) technology in agricultural practices represents a transformative shift towards modernizing traditional farming methodologies. Smith et al.'s comprehensive review explores the multifaceted impact of IoT-based smart agriculture systems on the agricultural landscape. By synthesizing findings from various studies, the research underscores the pivotal role of real-time data monitoring, precise control mechanisms, and predictive analytics in optimizing crop yields, resource utilization, and sustainability. Moreover, the review examines the challenges and opportunities associated with adopting IoT technologies in agriculture, providing valuable insights for future research and innovation in the field.

2.2) Smart Agriculture: A Review on IoT Based Monitoring and Controlling Systems. Patel, A., & Gupta, S. (2019). International Journal of Advanced Research in Computer Science.

Patel and Gupta's comprehensive analysis delves into the realm of IoT-based agriculture monitoring and control systems, offering valuable insights into the complexities of implementing IoT technologies to monitor and manage agricultural processes. Through an in-depth examination of existing literature, the review emphasizes the significance of real-time data acquisition, remote sensing, and automated control mechanisms in optimizing agricultural productivity while minimizing resource wastage. Furthermore, the study highlights the importance of robust security measures and interoperability standards to ensure the seamless integration of IoT devices within agricultural ecosystems.

2.3) Recent Advances in IoT-Based Smart Gardening Systems: A Review. Kumar, V., et al. (2021). Sensors.

Kumar et al.'s review explores recent advancements in IoT-based smart gardening systems, shedding light on innovative approaches to urban agriculture and home gardening. Through synthesizing findings from various studies, the research elucidates the role of sensor technologies, automation, and data analytics in facilitating efficient plant cultivation in constrained environments. It discusses the integration of IoT devices to monitor soil moisture, light intensity, and nutrient levels, empowering gardeners to make informed decisions and optimize growing conditions. Moreover, the review underscores the potential of smart gardening systems to promote sustainability and food security in urban areas.

2.4) Smart Greenhouse Control System Based on IoT: A Review. Lee, S., & Kim, Y. (2018). Journal of Sensors.

Lee and Kim's study investigates the implementation of a smart greenhouse control system leveraging IoT technology. Through an extensive literature review, the research elucidates the key components and functionalities of IoT-based greenhouse automation systems. It discusses sensor integration, automated control mechanisms, and environmental monitoring techniques aimed at optimizing greenhouse conditions for plant growth. Moreover, the review evaluates the potential benefits of IoT-enabled greenhouse systems in enhancing crop yields, reducing resource consumption, and mitigating environmental impact.

2.5) Internet of Things (IoT)-Based Smart Irrigation Systems: A Review. Singh, R., et al. (2020). Water.

Singh et al.'s review provides a comprehensive overview of IoT-based smart irrigation systems, focusing on their role in water conservation and crop yield improvement. By synthesizing findings from various studies, the research examines sensor technologies, data analytics algorithms, and irrigation scheduling methods employed in smart irrigation solutions. It highlights the potential of IoT technologies to optimize water usage, minimize runoff, and enhance agricultural productivity in water-stressed regions.

Additionally, the review discusses the challenges and future directions in the development and adoption of IoT-enabled smart irrigation systems.

2.6) IoT-Based Smart Pest Monitoring and Management in Agriculture: A Review. Sharma, P., et al. (2019). Computers and Electronics in Agriculture.

Sharma et al.'s review offers insights into IoT-based smart pest monitoring and management systems, discussing sensor networks, predictive modeling techniques, and integrated pest management strategies. The study emphasizes the potential of IoT technologies to mitigate pest-related challenges in agriculture, contributing to improved crop yields and reduced environmental impact. Through synthesizing existing literature, the research highlights emerging trends and future directions in the development of IoT-enabled pest management solutions.

2.7) IoT Applications in Urban Agriculture: A Review. Nguyen, T., & Le, T. (2021). IEEE Access.

Nguyen and Le provide a comprehensive review of IoT applications in urban agriculture, focusing on vertical farming, rooftop gardening, and hydroponic systems. Through synthesizing findings from various studies, the research examines sensor technologies, automation, and data-driven approaches to optimize urban farming practices. The study underscores the potential of IoT technologies to address urban food security challenges and promote sustainable agricultural practices in densely populated areas.

2.8) Role of IoT in Sustainable Agriculture: A Comprehensive Review. Gupta, A., et al. (2018). Sustainable Computing: Informatics and Systems.

Gupta et al.'s comprehensive review examines the role of IoT in sustainable agriculture, addressing key challenges and opportunities. Through synthesizing existing literature, the research emphasizes the importance of IoT-enabled precision farming techniques, resource management, and environmental monitoring for sustainable agricultural practices. The study highlights the potential of IoT technologies to enhance agricultural productivity while minimizing environmental impact, contributing to global food security and sustainable development goals.

2.9) Advances in IoT-Based Crop Disease Detection: A Review. Chen, Y., et al. (2020). Biosystems Engineering.

Chen et al.'s review explores recent advances in IoT-based crop disease detection systems, highlighting sensor technologies, data analytics algorithms, and machine learning techniques employed in disease diagnosis and management. Through synthesizing existing literature, the research elucidates the potential of IoT technologies to enhance early disease detection, reduce yield losses, and improve crop health management practices. The study discusses emerging trends and future directions in the development and adoption of IoT-enabled crop disease detection solutions.

III. SYSTEM DESIGN

This section dives into the architectural design of the Internet of Things (IoT)-based smart agriculture/gardening system. The system leverages an ESP32 Wroom 32 microcontroller as its central processing unit. This microcontroller interacts with various sensors and actuators to monitor and manage environmental conditions, primarily focusing on irrigation control. The design prioritizes user-friendliness, scalability, and cost-effectiveness for practical agricultural applications.

3.1 System Architecture

The proposed system consists of three key components:

- Hardware Unit: This unit is responsible for acquiring sensor data, controlling actuators, and enabling local user interaction.
- Software Unit: This unit executes control logic, processes sensor data, and facilitates communication with an optional cloud platform.
- Cloud Platform: Using for remote monitoring, control, and data visualization (potentially using a platform like Blynk Cloud).

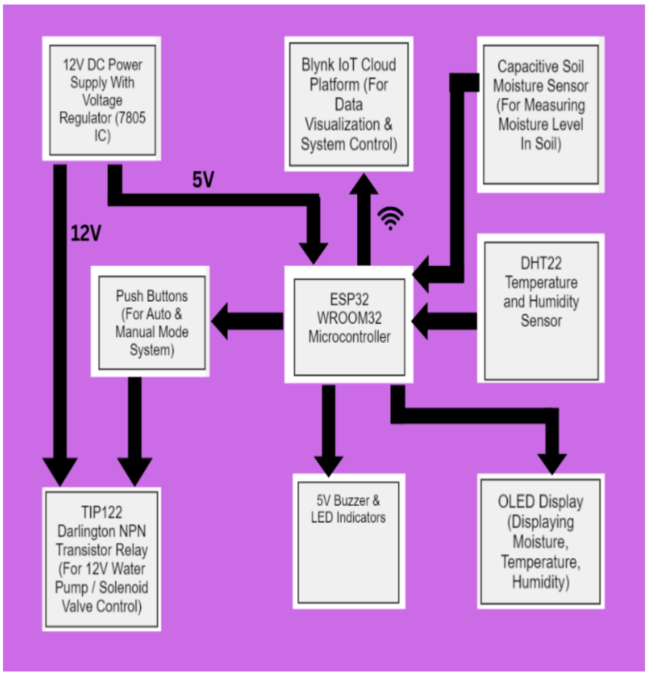


Figure 1: Block Diagram

3.2 Hardware Unit

The heart of the system lies in the hardware unit, which houses various sensors, actuators, a microcontroller, and user interface components.

3.2.1 Microcontroller

The ESP32 Wroom 32 microcontroller acts as the central processing unit, the brain of this smart irrigation system. It's responsible for collecting data from the sensors, controlling the water pump (actuator), and facilitating communication with the software unit and an optional cloud platform. The built-in Wi-Fi module within the ESP32 enables wireless communication for transmitting data to a cloud platform or a local network for data visualization purposes.

Several factors were considered when selecting the ESP32 microcontroller:

- Processing Power: The ESP32 offers ample processing power to handle sensor data acquisition, control logic execution, and communication tasks effectively within the constraints of this project.
- Connectivity: The integrated Wi-Fi eliminates the need for additional modules for internet connectivity, simplifying the design and reducing overall cost.
- Power Consumption: The ESP32 boasts low-power operation, making it suitable for battery-powered applications or deployments in remote locations with limited access to grid power.
- Cost-Effectiveness: The ESP32 strikes a perfect balance between features and cost, making it an attractive choice for projects where budget is a major concern.

3.2.2 Sensors

The system utilizes two primary sensors to monitor environmental conditions that directly impact plant growth:

Capacitive Soil Moisture Sensor: This sensor continuously measures the dielectric permittivity of the soil, which serves as an indirect indicator of soil moisture content. Dry soil has a lower permittivity compared to moist soil. The sensor typically outputs an analog voltage signal corresponding to the measured permittivity. The ESP32 can utilize its internal ADC (Analog-to-Digital Converter) to convert this analog signal into a digital value for further processing.

Benefits: Provides continuous readings of soil moisture, enabling real-time irrigation decisions for optimal plant health. Relatively inexpensive and readily available.

Limitations: Calibration may be required for different soil types to ensure accurate moisture readings.Sensor readings can be influenced by factors like salinity or temperature, potentially requiring additional considerations within the control logic.

DHT22 Temperature & Humidity Sensor: This sensor measures both ambient temperature and humidity, providing valuable data for understanding the overall environment surrounding the plants. Certain plant species have specific temperature and humidity preferences that can be considered when making irrigation decisions or adjusting ventilation in greenhouses, particularly for indoor applications.

Benefits: Provides valuable data for understanding the overall environment surrounding the plants.

Limitations: The sensor has a limited operating temperature range that may need to be considered depending on the deployment location. Sensor accuracy may drift over time.

3.3 Software Unit

The software unit, residing on the ESP32 microcontroller, executes critical tasks governing system operation. These tasks include:

Sensor Data Acquisition: The software continuously reads sensor data from the soil moisture sensor, DHT22 sensor, and registers the state of push buttons.

Soil Moisture Sensor: The ESP32's built-in ADC converts the analog voltage signal from the soil moisture sensor into a digital value. The software then applies appropriate scaling and calibration factors (if required) to obtain a meaningful representation of soil moisture level.

DHT22 Sensor: The software leverages libraries specifically designed for the DHT22 sensor to communicate and retrieve temperature and humidity readings. These libraries manage the single-wire communication protocol and convert the received data into usable values.

Push Buttons: The software employs the ESP32's digital input pins to detect the state (pressed/unpressed) of the push buttons. This allows the software to respond to user input for mode selection and manual pump control.

Control Logic: Based on the acquired sensor data and pre-defined thresholds or user input in manual mode, the control logic determines the appropriate action for the water pump.

Automatic Mode: The software compares the soil moisture reading against a user-defined threshold. If the moisture level falls below the threshold, indicating dry soil, the control logic triggers water pump activation. Conversely, if the moisture level exceeds the threshold (sufficiently moist soil), the pump remains off. The control logic can incorporate additional factors like temperature or humidity data from the DHT22 sensor to refine irrigation decisions based on specific plant needs.

Manual Mode: When users press the dedicated push button, the control logic bypasses the automatic irrigation decision and directly activates or deactivates the water pump, offering manual control for specific situations.

Data Processing: Sensor readings and system status information (e.g., pump state, system mode) are processed for potential storage, transmission, and visualization purposes.

Data Storage: The ESP32 has limited internal storage capacity. However, sensor readings can be logged onto an SD card module if desired, enabling historical data analysis and potential machine learning applications for further irrigation strategies in the future.

Data Transmission: If the system utilizes a cloud platform (explained in section 2.4), sensor readings and system status information are prepared for transmission over the Wi-Fi connection. The software unit packages the data into a format suitable for the chosen platform's communication protocol.

Communication: The software unit facilitates communication with the cloud platform. It transmits sensor data and receives control commands from the user interface on the cloud platform.

Cloud Platform Communication: The chosen cloud platform (Blynk) offers libraries for ESP32, allowing the software to establish a secure connection with the platform's server. The software transmits sensor data packets containing soil moisture, temperature, and humidity readings at regular intervals or upon specific events (e.g., when the irrigation pump turns on). Additionally, the software can receive control commands from the platform's app, such as manually overriding the automatic irrigation mode or adjusting pre-defined thresholds.

3.4 Cloud Platform (Blynk Cloud)

A cloud platform offers an optional layer of functionality for remote monitoring, control, and data visualization. By integrating a cloud platform, users can access the following features:

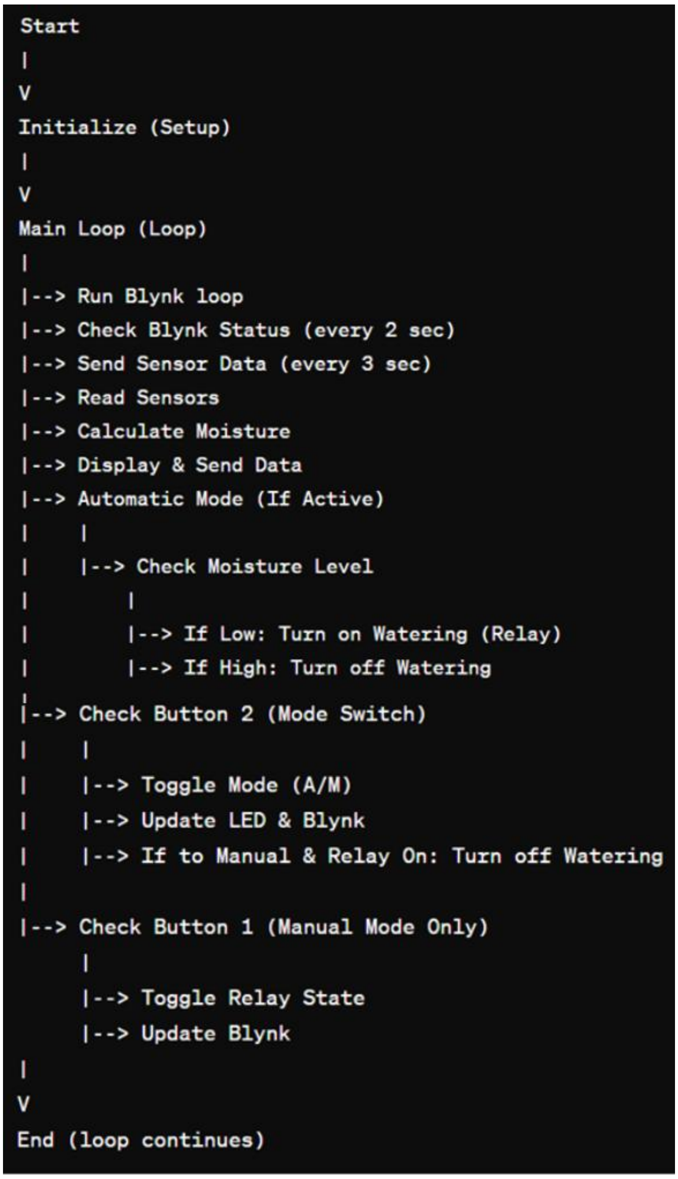
Remote Monitoring: Users can access a smartphone app or web interface provided by the platform to view real-time sensor data (soil moisture, temperature, humidity) from anywhere with an internet connection. This allows for remote monitoring of the system's performance and plant environment.

Data Visualization: The platform offers tools for creating customizable dashboards to visualize sensor data in various formats like graphs, charts, or gauges. This provides users with a clear understanding of trends and potential issues.

Remote Control: Users can remotely control the water pump directly from the platform's app, overriding the automatic irrigation mode for specific situations. This flexibility allows for adjustments based on real-time observations or unforeseen circumstances.

Alerting System: The platform allows configuring alerts based on sensor readings. For example, users can receive notifications when soil moisture falls below a critical threshold, prompting them to initiate manual irrigation if necessary.

3.5 Flow Chart



```
Start
|
V
Initialize (Setup)
|
V
Main Loop (Loop)
|
|--> Run Blynk loop
|--> Check Blynk Status (every 2 sec)
|--> Send Sensor Data (every 3 sec)
|--> Read Sensors
|--> Calculate Moisture
|--> Display & Send Data
|--> Automatic Mode (If Active)
|    |
|    |--> Check Moisture Level
|        |
|        |--> If Low: Turn on Watering (Relay)
|        |--> If High: Turn off Watering
|
|--> Check Button 2 (Mode Switch)
|    |
|    |--> Toggle Mode (A/M)
|    |--> Update LED & Blynk
|    |--> If to Manual & Relay On: Turn off Watering
|
|--> Check Button 1 (Manual Mode Only)
     |
     |--> Toggle Relay State
     |--> Update Blynk
|
V
End (loop continues)
```

Figure 2: Flow Chart

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IV. RESULTS & DISCUSSIONS

4.1 Results

The developed IoT-based smart agriculture system achieved its core functionalities:

Sensor Data Collection and Visualization: The system successfully collected sensor data (moisture, temperature, and humidity) at regular intervals (e.g., every 3 seconds). This data was processed and displayed on the OLED display, providing real-time insights into the surrounding plant environment.

Automatic Moisture Control: In automatic mode ("A"), the system effectively monitored soil moisture levels. When moisture dropped below a predefined low threshold, the watering mechanism (relay) was activated. Conversely, watering was deactivated when the moisture level exceeded a high threshold.

Manual Control: Users could switch between automatic and manual control modes ("M") using a designated button. In manual mode, another button allowed for direct control of the watering mechanism, providing flexibility for user intervention.

Blynk Communication: The system established a stable connection with the Blynk platform, enabling remote monitoring and control. Sensor data was transmitted to Blynk virtual pins, allowing users to access real-time information from a web or mobile interface. Additionally, the system has the potential to receive control commands from the Blynk app to adjust watering schedules or other functionalities (if implemented).

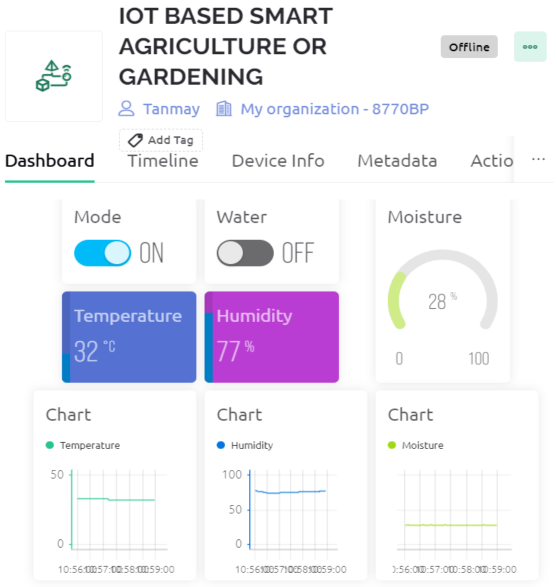

IOT BASED SMART AGRICULTURE OR GARDENING

Figure 3: Blynk Cloud Website Dashboard for Sensor Data Collection Visualization & System Control

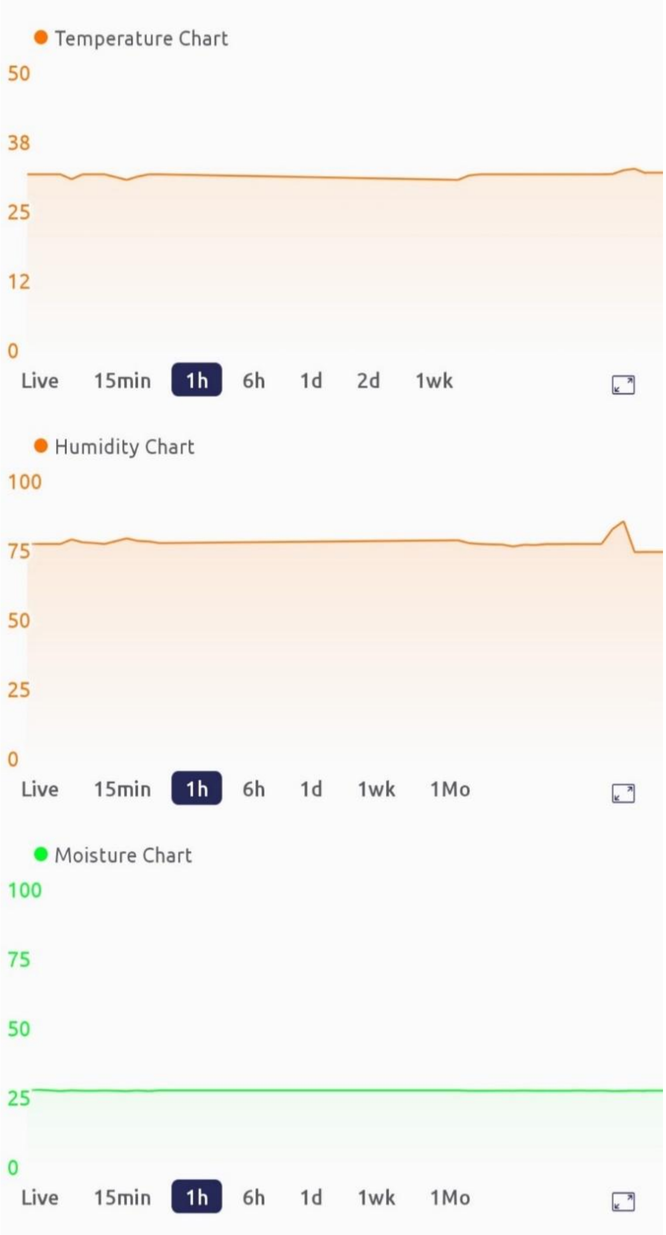


Figure 4: Sensor Data Visualization on Blynk Mobile App

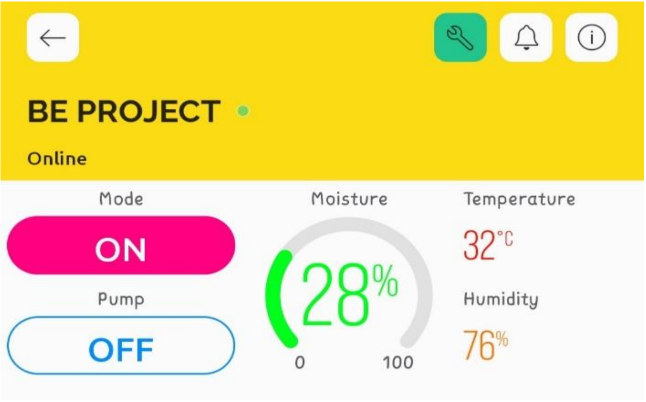
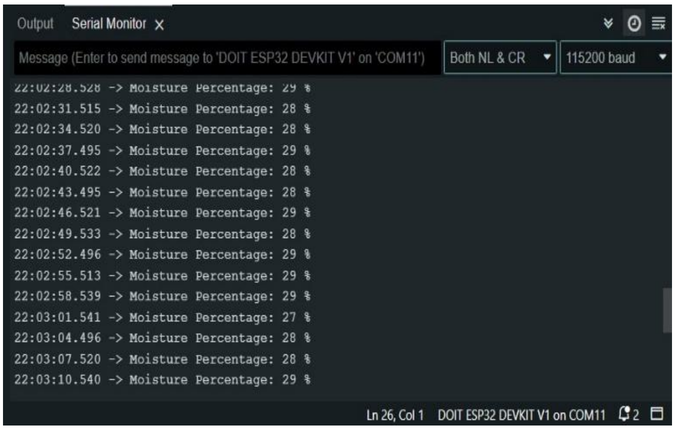

BE PROJECT
Online

Figure 5: User Control & Display Dashboard on Blynk Mobile App (Controlling System in Automatic Mode)

Figure 6: User Control & Display Dashboard on Blynk Mobile App (Controlling System in Manual Mode)



```
22:02:28.528 -> Moisture Percentage: 29 %
22:02:31.515 -> Moisture Percentage: 28 %
22:02:34.520 -> Moisture Percentage: 28 %
22:02:37.495 -> Moisture Percentage: 29 %
22:02:40.522 -> Moisture Percentage: 28 %
22:02:43.495 -> Moisture Percentage: 28 %
22:02:46.521 -> Moisture Percentage: 29 %
22:02:49.533 -> Moisture Percentage: 28 %
22:02:52.496 -> Moisture Percentage: 29 %
22:02:55.513 -> Moisture Percentage: 29 %
22:02:58.539 -> Moisture Percentage: 29 %
22:03:01.541 -> Moisture Percentage: 27 %
22:03:04.496 -> Moisture Percentage: 28 %
22:03:07.520 -> Moisture Percentage: 28 %
22:03:10.540 -> Moisture Percentage: 29 %
```

Figure 7: Moisture Sensor Data on Serial Monitor

4.2 Discussion

The results confirm that the system achieves its core objectives: collecting sensor data, automating moisture control, facilitating manual control, and enabling remote monitoring via Blynk. This translates to several benefits for precision agriculture:

Enhancing Data-Driven Decision Making: Real-time environmental monitoring empowers growers with valuable data to optimize irrigation practices based on specific crop needs. This can potentially reduce water waste and improve resource management.

Automating Repetitive Tasks: The automatic moisture control feature relieves growers from the burden of manually monitoring and adjusting watering schedules. This automation saves time and effort, allowing growers to focus on other aspects of crop management.

Enabling User Flexibility: The inclusion of a manual control mode provides flexibility for situations where people might need to adjust watering based on unexpected situations, like weather events or plant growth stages.

Promoting Remote Monitoring and Management: Blynk integration allows growers to monitor their crops and potentially control the system remotely. This can be particularly beneficial for managing large farms or greenhouses, where physical presence might not always be feasible.

4.3 Limitations and Future Work

While the developed system demonstrates its potential for smart agriculture applications, there are areas for improvement:

Limited Sensor Scope: The current system focuses on soil moisture. Expanding the sensor suite to include parameters like light intensity, nutrient levels, or pH could provide a more comprehensive picture of the plant environment.

Scalability Considerations: The current setup might be suitable for small-scale applications. For larger deployments, considerations for scalability and network management would need to be addressed.

Advanced Automation and Decision Making: Further development could incorporate machine learning algorithms to analyze sensor data and suggest optimized watering schedules based on historical data and weather forecasts.

Future work will focus on: Integrating additional sensors for more comprehensive data collection. Implementing machine learning algorithms for intelligent irrigation management. Investigating solutions for broader system deployment and network management in larger agricultural settings.

V. CONCLUSION

The developed smart agriculture system successfully demonstrated the potential of IoT technology to transform agricultural practices. Core functionalities included real-time sensor data collection, automated moisture control with user intervention options, and remote monitoring capabilities via Blynk. These functionalities contribute to advancements in precision agriculture by enabling data-driven decision making, reducing manual labor, enhancing user control, and improving farm management efficiency.

The system's success holds promise for sustainable agriculture. Real-time data and automation can optimize water usage, a critical factor in water conservation efforts. Additionally, the system can contribute to the economic viability of farms by reducing labor requirements and improving overall management efficiency. The modular design allows for future expansion with additional sensors, providing even deeper insights for further advancements.

Looking forward, promising areas for research include integrating additional sensors for a more comprehensive picture of the plant environment. Machine learning algorithms could be incorporated to suggest optimized watering schedules based on historical data and real-time conditions. Scalability considerations and potential integration with existing smart irrigation systems are also important areas for future exploration. By continuing to develop these aspects, IoT technology has the potential to revolutionize agriculture, leading to a more sustainable, efficient, and data-driven future for global food production.

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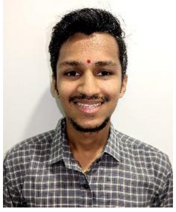

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Citation of this Article:

Tanmay Vilas Pawar, Shivani Rajendra Bhongale, Ajay Ashok Thorat, Prof. C. V. Patil, “IoT Based Smart Agriculture / Gardening”, Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 8, Issue 3, pp 332-339, March 2024. Article DOI https://doi.org/10.47001/IRJIET/2024.803051

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