Iot-Enabled Smart Garden Irrigation And Monitoring System Using Esp32 For Efficient Home Automation

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ABSTRACT

Water scarcity and improper irrigation practices are major challenges affecting home gardening efficiency and plant health. Traditional irrigation methods often rely on manual watering or fixed timing mechanisms, which do not adjust according to real-time environmental conditions. This leads to problems such as water wastage, over-irrigation, and insufficient hydration of plants. To address these limitations, this research proposes an IoT-enabled smart garden irrigation system using the ESP32 microcontroller. The system integrates soil moisture sensors, humidity sensors, water level sensors, and automated pump control to deliver precise irrigation based on plant needs. The ESP32's built-in Wi-Fi connectivity allows real-time data monitoring, remote control, and smartphone-based notifications through cloud platforms. The design improves water conservation, reduces human labor, and ensures healthier plant growth through intelligent automation. Additionally, the framework supports scalability for multi-zone gardens and smart home integration. Overall, the proposed IoT-based solution offers an efficient, user-friendly, and sustainable approach for modern home garden irrigation systems.

Keywords: Internet of Things (IoT), Smart Irrigation System, ESP32 Microcontroller, Soil Moisture Sensor, Automated Watering, Home Garden Automation, Water Conservation, Environmental Monitoring, Wireless Sensor Networks, Smart Agriculture.

I. INTRODUCTION

Home gardening has become increasingly popular as people strive for healthier living, personalized food production, and aesthetically pleasing surroundings. However, maintaining garden health requires consistent watering practices, which depend on environmental factors such as soil moisture, humidity, and plant water requirements. Manual irrigation often results in irregular watering, especially for individuals with busy schedules. Timer-based irrigation systems offer partial automation but lack responsiveness to dynamic environmental conditions. With advancements in the Internet of Things (IoT), smart irrigation solutions have emerged as a powerful alternative by integrating sensors, connectivity, and automation. Among IoT development boards, the ESP32 stands out due to its built-in Wi-Fi/Bluetooth support, low power consumption, and high processing capability. By leveraging sensor data and cloud connectivity, the ESP32 can efficiently monitor garden conditions and control irrigation automatically or remotely. This study focuses on the design and implementation of a smart garden irrigation system using ESP32, aimed at minimizing water usage, improving efficiency, and enhancing overall garden health through intelligent automation.

II. Related Words

Recent developments in the Internet of Things (IoT) have significantly improved the efficiency of irrigation systems by enabling real-time monitoring and automated control of water resources. Traditional irrigation methods often rely on manual watering or fixed scheduling, which can lead to inefficient water usage. To overcome these issues, several researchers have proposed IoT-based smart irrigation systems that integrate sensors, microcontrollers, and wireless communication technologies to monitor environmental parameters and control irrigation processes automatically. Rawal presented an IoT-based irrigation framework that uses soil moisture sensing and automated control mechanisms to optimize water usage in agricultural fields, demonstrating the potential of IoT technology in sustainable irrigation management [1].

Several modern irrigation systems utilize microcontrollers such as ESP32 to provide wireless connectivity and real-time monitoring capabilities. Pereira et al. developed an IoT-enabled smart drip irrigation system using ESP32 that allows remote monitoring and control of irrigation through internet-based platforms. Their study demonstrated improved water efficiency and better crop management through automated irrigation decisions [2]. Similarly, Mohiuddin et al. proposed an IoT-based agriculture irrigation system that integrates environmental sensors to collect soil and atmospheric data, enabling intelligent irrigation decisions that improve crop productivity and reduce water wastage [3].

Sensor-based monitoring plays a crucial role in smart irrigation systems. El Mezouari et al. introduced an IoT-driven irrigation system using multiple sensors such as soil moisture, temperature, and humidity sensors to monitor environmental conditions and automate irrigation accordingly. Their work highlighted how real-time sensing combined with IoT communication improves water management and irrigation efficiency [4]. Furthermore, Manocha et al. proposed a digital-twin-inspired IoT irrigation model that uses advanced data processing and monitoring to optimize irrigation schedules for precision agriculture applications [5].

Recent research has also focused on improving system scalability and energy efficiency. Aisyah et al. designed an ESP32-based IoT irrigation system that enables remote monitoring through wireless communication networks and cloud platforms. Their system supports automated watering mechanisms and real-time data visualization for better plant management [6]. Similarly, Sidik et al. introduced a smart irrigation system powered by photovoltaic energy combined with soil moisture sensors to create a sustainable and energy-efficient irrigation solution suitable for remote agricultural environments [7].

In addition to agricultural applications, IoT irrigation systems have also been explored for sustainable water management and smart gardening. Padiachy et al. developed an IoT-based irrigation model that improves water conservation and resource utilization through automated monitoring systems [8]. Mishra et al. proposed a soil moisture sensor-based irrigation system that automatically activates watering when soil moisture falls below a threshold value, thereby preventing both under-irrigation and over-irrigation [9].

Earlier research on wireless monitoring systems also laid the foundation for modern IoT irrigation solutions. Chavan and Karande demonstrated a wireless monitoring system using ZigBee technology to measure soil moisture, humidity, and temperature in agricultural environments, enabling automated irrigation control [10]. Later, IoT frameworks further expanded these concepts by integrating internet connectivity and cloud-based monitoring. Divya et al. developed an IoT-based irrigation system capable of remotely monitoring soil conditions and controlling water pumps through smart devices [11].

More advanced irrigation architectures have been proposed in recent years to support precision agriculture and smart farming environments. Rathore et al. developed a smart irrigation framework that integrates IoT sensors and data analysis techniques to improve irrigation efficiency and agricultural productivity [12]. Similarly, Anitha et al. proposed an automated irrigation system that uses IoT technology for continuous monitoring of soil parameters and automatic control of irrigation pumps [13].

Recent studies also emphasize integrating IoT irrigation with climate monitoring systems. Castro-Vargas et al. proposed an ESP32-based smart drip irrigation system that monitors greenhouse climate conditions and soil parameters simultaneously, enabling intelligent irrigation scheduling and environmental control [14]. Likewise, Benedict Tephila et al. developed an IoT-enabled automated irrigation system using multiple sensor parameters to optimize water supply and enhance plant growth in agricultural fields [15].

Overall, the literature indicates that IoT-based irrigation systems significantly improve water efficiency, reduce manual intervention, and support sustainable agriculture practices. However, there remains a need for scalable, user-friendly systems designed specifically for home garden automation, which motivates the development of the proposed IoT-enabled smart garden irrigation and monitoring system using ESP32.

III. PROPOSED MODEL

The proposed IoT-Enabled Smart Garden Irrigation and Monitoring System is designed to automate watering and environmental monitoring in home gardens using the ESP32 microcontroller. The system integrates multiple sensors, communication modules, and an automated irrigation mechanism to ensure efficient water management and healthy plant growth. The ESP32 acts as the central controller due to its built-in Wi-Fi capability, processing power, and ability to connect with cloud platforms for real-time monitoring. The system continuously collects environmental data from sensors such as soil moisture sensors, humidity sensors, and water level sensors to determine the irrigation requirements of plants.

In the proposed architecture, the soil moisture sensor plays a key role in measuring the moisture content of the soil. The sensor continuously sends analog or digital signals to the ESP32 controller. When the moisture level falls below a predefined threshold value, the ESP32 automatically activates a water pump through a relay module to supply water to the plants. Once the soil moisture level reaches the required threshold, the controller turns off the pump to prevent over-irrigation and water wastage. This automated decision-making process ensures that plants receive the appropriate amount of water based on real-time environmental conditions.

The system also integrates humidity and environmental sensors to monitor surrounding climatic conditions that influence plant growth. These sensors provide additional data to the ESP32, allowing the system to analyze environmental variations that may affect irrigation requirements. Furthermore, a water level sensor is used to monitor the water availability in the storage tank, ensuring that the irrigation system operates only when sufficient water is available. If the water level is low, the system can generate alerts to notify the user to refill the tank.

One of the key features of the proposed model is remote monitoring and control through IoT connectivity. The ESP32 transmits collected sensor data to a cloud platform using Wi-Fi, enabling users to monitor soil moisture, humidity levels, and irrigation status through a smartphone or web-based interface. The system can also send notifications or alerts when watering is triggered or when abnormal conditions are detected. This remote access improves user convenience and allows gardeners to monitor their plants even when they are not physically present.

Additionally, the proposed system supports scalability and smart home integration. Multiple sensors and irrigation zones can be added to manage larger gardens or multiple plant beds. The architecture can also be integrated with other smart home systems, enabling automated scheduling and advanced data analysis for optimized irrigation management. By combining sensor-based monitoring, automated pump control, and IoT communication, the proposed model provides an efficient, cost-effective, and sustainable solution for modern home garden irrigation and monitoring systems.

IV. PROPOSED SYSTEM

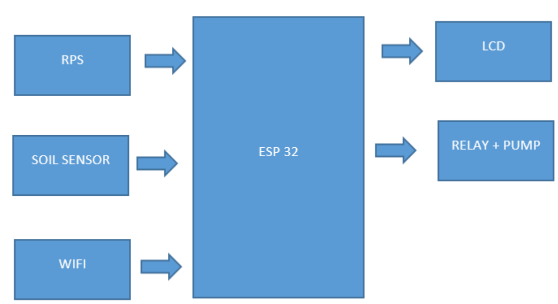

Fig.1.Block diagram

The block diagram illustrates the architecture of the IoT-Enabled Smart Garden Irrigation and Monitoring System using ESP32. In this system, the ESP32 microcontroller acts as the central processing unit that receives input data from various components and controls the overall irrigation process. The soil moisture sensor continuously measures the moisture level of the soil and sends the readings to the ESP32 for analysis. A regulated power supply (RPS) provides the necessary electrical power required for the ESP32 and other connected modules to operate reliably. The system also uses Wi-Fi connectivity, enabling the ESP32 to transmit sensor data to cloud platforms or mobile applications for remote monitoring and control. Based on the soil moisture readings, the ESP32 decides whether irrigation is required. If the soil moisture level falls below a predefined threshold, the controller activates a relay module, which in turn switches on the water pump to irrigate the plants automatically. Once the desired moisture level is reached, the pump is turned off to prevent water wastage. Additionally, an LCD display is connected to the ESP32 to provide real-time information such as soil moisture levels, system status, and irrigation activity. This integrated architecture enables efficient water management, automation of irrigation processes, and real-time monitoring for smart home gardening applications.

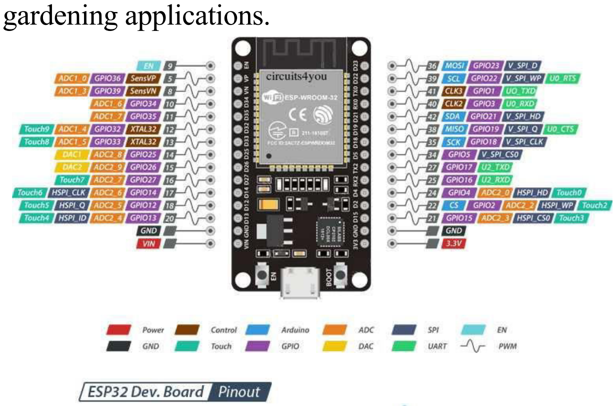

Fig.2. ESP32 Peripherals Features

V. RESULTS AND DESCUSSIONS

The proposed IoT-Enabled Smart Garden Irrigation and Monitoring System Using ESP32 for Efficient Home Automation improves garden management by integrating IoT communication, embedded processing, and sensor-based environmental monitoring. The system continuously monitors the soil condition and environmental parameters in home gardens using sensors connected to the ESP32 microcontroller. Sensors such as the soil moisture sensor, humidity sensor, and water level sensor detect soil conditions and environmental changes that influence plant growth. When the soil moisture level falls below a predefined threshold, the ESP32 controller processes the sensor data and automatically activates the irrigation pump through a relay module. At the same time, real-time data is transmitted through Wi-Fi connectivity to cloud platforms, allowing users to monitor the garden remotely through a smartphone or web interface. This automated irrigation and monitoring capability ensures efficient water usage and improves plant health.

The specifications of the components used in the proposed system are presented in Table 1. The ESP32 microcontroller acts as the central controller responsible for processing sensor inputs and enabling IoT communication. The soil moisture sensor measures the moisture level in the soil and provides real-time feedback to determine whether irrigation is required. The humidity sensor monitors environmental humidity levels that affect plant growth conditions. The water level sensor checks the availability of water in the storage tank to ensure proper irrigation operation. The Wi-Fi module, integrated within the ESP32 controller, enables wireless communication between the system and cloud platforms for remote monitoring. The relay module and water pump are responsible for automatically supplying water to plants when irrigation is required, while the LCD display provides real-time system status and sensor readings.

TABLE 1: SENSOR AND COMPONENT SPECIFICATION

SI.NO	Components	Specifications
1	ESP32 Microcontroller	Operating Voltage: 3.3–5V, Built-in Wi-Fi, Dual-core processor
2	Soil Moisture Sensor	Measures soil moisture level for irrigation control
3	Humidity Sensor	Detects environmental humidity affecting plant growth
4	Water Level Sensor	Monitors water level in storage tank
5	Wi-Fi Module	Enables IoT

SI.NO	Components	Specifications
		communication and remote monitoring
6	Relay Module	Controls switching of the irrigation pump
7	Water Pump	Supplies water to plants automatically
8	LCD Display	Displays real-time sensor values and system status
9	Power Supply	Regulated power source for system operation

The hardware implementation integrates all sensing components with the ESP32 microcontroller to create an intelligent irrigation and monitoring system. During operation, the soil moisture sensor continuously monitors soil conditions and sends data signals to the ESP32 controller. If the moisture level drops below the defined threshold value, the ESP32 automatically activates the relay module, which turns on the water pump to irrigate the plants. Once the soil moisture reaches the desired level, the controller automatically switches off the pump to prevent over-irrigation and conserve water. The water level sensor ensures that the system operates only when sufficient water is available in the storage tank.

The system also supports real-time monitoring and remote control through IoT connectivity. The ESP32 transmits sensor data such as soil moisture levels and humidity conditions to cloud platforms using Wi-Fi communication. Users can monitor these values through a mobile application or web interface and receive notifications when irrigation is triggered or when abnormal conditions are detected. The LCD display connected to the ESP32 also shows real-time system information locally, allowing users to easily observe the system's operational status.

The experimental results demonstrate that the proposed system effectively automates garden irrigation while reducing water wastage. The soil moisture sensor accurately detects soil conditions, enabling timely activation of the irrigation pump when watering is required. The ESP32 Wi-Fi connectivity ensures stable transmission of monitoring data, allowing users to remotely track the irrigation process. The automated irrigation mechanism ensures that plants receive an adequate water supply without manual intervention.

Overall, the implementation of the proposed system significantly improves home garden irrigation efficiency by enabling continuous environmental monitoring, automated watering control, and remote IoT-based management. The integration of sensors, embedded processing, and wireless communication reduces human effort while promoting sustainable water usage. By combining intelligent sensing technologies with IoT connectivity, the proposed system provides a cost-effective, scalable, and reliable smart irrigation solution suitable for modern home gardening and smart home automation environments.

VI. CONCLUSION AND FUTURE SCOPE

Conclusion:

The implementation of an IoT-enabled smart home garden irrigation system using ESP32 offers a transformative solution to the limitations of traditional irrigation methods. By integrating real-time sensing, automation, and cloud connectivity, the system ensures efficient water usage, enhances plant health, and reduces the need for manual intervention. The literature highlights the evolution of irrigation technologies from basic sensor-based systems to intelligent IoT-driven platforms capable of remote monitoring and predictive control. The proposed system, supported by ESP32's robust processing and connectivity features, presents an effective, scalable, and sustainable irrigation approach suitable for modern smart homes. Future enhancements may include AI-driven irrigation prediction, solar-powered operation, and multi-zone garden control for broader deployment.

Future Scope:

The proposed IoT-Enabled Smart Garden Irrigation and Monitoring System using ESP32 can be further enhanced by integrating advanced technologies to improve efficiency, scalability, and automation. Future improvements may include the incorporation of machine learning algorithms to analyze historical soil and environmental data and predict optimal irrigation schedules automatically. Additional sensors such as temperature, rainfall, and light intensity sensors can be integrated to provide more accurate environmental monitoring and intelligent irrigation decisions. The system can also be expanded to support multi-zone irrigation management for larger gardens or agricultural fields. Integration with mobile applications, cloud-based analytics, and smart home platforms such as Google Home or Alexa can further enhance user control and convenience. Moreover, the use of solar-powered energy systems can make the irrigation framework more sustainable and suitable for remote locations. These enhancements would transform the proposed system into a more intelligent, energy-efficient, and fully autonomous smart irrigation solution for modern gardening and agriculture.

VII. REFERENCES

[1]. S. Rawal, “IoT Based Smart Irrigation System,” *International Journal of Computer Applications*, vol. 159, no. 8, pp. 7–11, Feb. 2017.
DOI: https://doi.org/10.5120/ijca2017913001

[2]. G. P. Pereira et al., “IoT-Enabled Smart Drip Irrigation System Using ESP32,” *Proceedings*, vol. 4, no. 3, 2023.
DOI: https://doi.org/10.3390/proceedings4030012

[3]. M. Mohiuddin et al., “Internet of Things (IoT)-Based Smart Agriculture Irrigation System,” *Engineering Proceedings*, vol. 82, no. 1, 2024.
DOI: https://doi.org/10.3390/engproc20240820099

[4]. A. El Mezouari et al., “Smart Irrigation System Based on IoT and Sensor Technologies,” *IFAC-PapersOnLine*, vol. 55, no. 10, pp. 392–397, 2022.
DOI: https://doi.org/10.1016/j.ifacol.2022.10.068

[5]. A. Manocha et al., “IoT Digital-Twin-Inspired Smart Irrigation Approach for Precision Agriculture,” *Sustainable Computing: Informatics and Systems*, 2024.
DOI: https://doi.org/10.1016/j.suscom.2023.100905

[6]. N. Aisyah et al., “Design of an IoT-Based Smart Irrigation System Using ESP32,” *Journal of Physics: Conference Series*, 2025.
DOI: https://doi.org/10.1088/1742-6596/2564/1/012020

[7]. A. R. Sidik et al., “Smart Irrigation Based on Soil Moisture Sensors with Photovoltaic Energy,” *Engineering Proceedings*, 2025.
DOI: https://doi.org/10.3390/engproc20251070017

[8]. V. Padiachy et al., “IoT Based Smart Irrigation System for Sustainable Agriculture,” *Atlantis Press*, 2025.
DOI: https://doi.org/10.2991/978-94-6463-066-6_14

[9]. A. K. Mishra et al., “IoT Based Smart Irrigation System Using Soil Moisture Sensors,” *SSRN Electronic Journal*, 2025.
DOI: https://doi.org/10.2139/ssrn.5227801

[10]. C. H. Chavan and P. V. Karande, “Wireless Monitoring of Soil Moisture, Temperature and Humidity Using ZigBee in Agriculture,” *International Journal of Engineering Trends and Technology*, 2015.
DOI: https://doi.org/10.14445/22315381/IJETT-V21P222

[11]. N. Divya et al., “Smart Irrigation System Using Internet of Things,” *International Conference on Computing, Power and Communication*, 2022.
DOI: https://doi.org/10.1109/ICCPC55978.2022.10072120

[12]. T. Rathore, D. K. Gupta, and N. Kumar, “IoT Based Smart Irrigation System for Precision Agriculture,” *IEEE International Conference on Smart Computing*, 2023.
DOI: https://doi.org/10.1109/ICSCCC56919.2023.10143920

[13]. A. Anitha, N. Sampath, and M. A. Jerlin, “IoT Based Automated Irrigation System,” *International Conference on Emerging Trends in Information Technology and Engineering*, 2020.
DOI: https://doi.org/10.1109/ic-etite47903.2020.324

[14]. C. Castro-Vargas et al., “IoT System with ESP32 for Smart Drip Irrigation and Climate Monitoring in Greenhouses,” 2025.
DOI: https://doi.org/10.13140/RG.2.2.21516.74886

[15]. M. Benedict Tephila et al., “Automated Smart Irrigation System Using IoT with Sensor Parameters,” *ICEARS Conference Proceedings*, 2022.
DOI: https://doi.org/10.1109/ICEARS53579.2022.975237