A PROJECT REPORT ON

IOT-BASED PLANT MONITORING SYSTEM

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Project Completion Certificate

Date: 10/05/2025

This is to certify that **Vivek Kansal** bearing Roll No.2101320130120, student of 4th year in the Department of Information Technology has completed the project work (KIT-851) from 10-Feb-25 to 10-May-25.

He worked on the Project Titled **"IOT-Based Plant Monitoring System"** under the guidance of **Ms. Archana Singh.**

This project work has not been submitted anywhere for any degree.

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ABSTRACT

Plants, being living organisms, require consistent monitoring of their environment to maintain proper growth and health. However, manual observation of parameters such as soil moisture, temperature, and humidity can be time-consuming, inconsistent, and inefficient. These limitations often result in overwatering, underwatering, or unfavourable growing conditions, especially when human intervention is delayed or absent.

To address this challenge, we propose an IoT-based Plant Monitoring System that uses real-time sensor data to automate and simplify plant care. This system integrates a network of sensors connected to a NodeMCU (ESP8266) microcontroller, which collects essential data such as soil moisture, ambient temperature, and humidity levels. The collected data is sent to Firebase, a real-time cloud database, and is then displayed on a dedicated website called Plant Sense, developed using HTML, CSS, and JavaScript.

The system also features an automated water pump controlled by a relay module, which activates when soil moisture drops below a set threshold. Additionally, users receive real-time email notifications in case of critical changes in environmental conditions.

By combining sensor feedback with automation and a user-friendly web interface, the proposed IoT system allows users to remotely monitor and manage plant health efficiently. This approach not only reduces the need for constant manual oversight but also ensures that plants receive timely care, especially in indoor or home settings.The ultimate goal of this system is to promote smarter, technology-assisted plant care through the effective use of IoT, thereby enhancing convenience, reliability, and plant longevity.

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Introduction

1.1 INTRODUCTION

In today's fast-paced world, the attention given to the daily care of plants has significantly decreased due to busy schedules and lack of proper knowledge. This often leads to improper watering, unsuitable temperature exposure, and other environmental stress factors that adversely affect plant growth [1]. The advancement in sensor technologies and the (IoT) offers a viable solution to monitor and maintain optimal conditions for plant health.

The IoT Based Plant Monitoring System is a smart solution designed to observe and manage critical plant parameters such as soil moisture, temperature, and humidity in real-time. It employs sensors integrated with a microcontroller (NodeMCU ESP8266) to collect data, which is then sent to a cloud-based platform (Firebase). The collected data is visualized on a web interface named Plant Sense, allowing users to access live updates remotely. This facilitates timely actions like watering the plant through an automated pump when moisture levels fall below the desired range.

The motivation behind this project is to create a system that not only aids in plant maintenance but also promotes smart, sustainable practices. Whether for household plants, indoor gardens, office greenery, or research settings, the system ensures that plants receive appropriate care without the need for constant human attention.

The system is cost-effective, energy-efficient, and scalable for future enhancements, such as AI-based prediction models or voice assistant integration. With the convergence of hardware and software, the project brings together automation, real-time monitoring, and remote accessibility into one seamless interface. [2]

By minimizing manual effort and ensuring precision in care, the IoT Based Plant Monitoring System contributes to healthier plants and a more convenient user experience. It exemplifies how simple yet innovative technology can address common issues effectively while being accessible to a broad user base.

1.2 PROBLEM STATEMENT

Maintaining optimal conditions for plant growth can be a tedious and inconsistent task when done manually. People often forget to water plants or do not understand the specific environmental requirements of different plant species. This lack of timely care leads to plant stress, stunted growth, or even plant death. Furthermore, traditional methods of observation are not precise and often fail to alert the user in real time.[3]

As urbanization increases and living spaces become more compact, people are turning to indoor plants for environmental and aesthetic benefits. However, in such setups, consistent monitoring becomes even more critical. There is a growing need for an intelligent system that can monitor key parameters like soil moisture, temperature, and humidity continuously and trigger alerts or actions when needed.

This project addresses the challenge of unmonitored plant care by designing a reliable, automated system based on IoT technology [4]. It not only ensures timely watering but also allows users to remotely monitor plant conditions. The aim is to reduce dependency on manual checks and to create an environment where plants are consistently maintained through automation and data-driven insights.

1.3 IDENTIFICATION AND NEED

The need for a plant monitoring system stems from the fact that manual care of plants is not always feasible, especially for individuals with busy schedules or limited horticultural knowledge. Many plant owners either overwater or underwater their plants due to a lack of real-time data on soil and atmospheric conditions. As a result, even well-intentioned care can be detrimental.

By identifying this gap, the project introduces an IoT-based solution that continuously monitors key parameters and automates irrigation when necessary. This kind of system is particularly useful for indoor plants, office greenery, school biology labs, or any setting where routine plant care may be neglected. With real-time updates, users can stay informed and take corrective measures instantly.[5]

The system also fills the need for a low-cost, scalable platform that combines modern web technologies with embedded hardware. It empowers users to understand and respond to plant needs better, reducing guesswork and improving overall plant health.

1.4 OBJECTIVE

The primary objective of this project is to develop a smart and cost-effective IoT-based system that automates and simplifies plant monitoring and care. The system focuses on providing users with real-time environmental data—specifically soil moisture, temperature, and humidity—through an intuitive web interface. By integrating sensor networks with cloud storage (Firebase) and real-time notification mechanisms, the project aims to create an intelligent environment for plant health monitoring.[6]

Another key objective is to implement a feedback-based control system that automates watering through a water pump whenever soil moisture falls below a critical threshold. This ensures timely irrigation without human intervention. The data is processed using a NodeMCU (ESP8266) microcontroller, making the system efficient, responsive, and wireless.

The project also emphasizes user accessibility by designing a lightweight, web-based platform (Plant Sense) that displays the latest plant health data in a user-friendly format. It allows users to monitor conditions from any location and receive notifications when parameters deviate from optimal ranges.

Through this system, the goal is to reduce plant neglect, conserve water, enhance convenience, and encourage the adoption of smart plant care solutions. The final objective is to deliver a prototype that is easy to set up, maintain, and expand, making it suitable for a wide range of users from hobbyists to researchers.[7]

1.5 UNIQUENESS OF THE INNOVATION

The proposed IoT Based Plant Monitoring System stands out for its integration of real-time data analytics, automated irrigation, and web-based monitoring on a unified platform. Unlike conventional plant care devices, this innovation offers email-based notifications, cloud-based data management, and scalability for multi-plant setups. The simplicity of design, low power consumption, and the use of open-source tools make it a unique and practical solution for smart plant care.

1.6 APPLICATIONS OF THIS PROJECT

The system has wide-ranging applications in both personal and institutional settings. It can be used in home gardens, indoor plant setups, office desks, classrooms, and laboratories to ensure consistent care and monitoring. Its automated features eliminate the need for daily manual checks, making it ideal for users who travel frequently or have irregular schedules [8]. Additionally, the system can be applied in urban green spaces and smart building integrations to enhance environmental aesthetics and sustainability. It promotes responsible plant care with minimal effort.

1.6.1 POTENTIAL AREAS OF APPLICATION IN INDUSTRY/MARKET

The IoT Based Plant Monitoring System holds potential across various sectors. In residential settings, it appeals to plant hobbyists, home automation enthusiasts, and environmentally conscious individuals. In the education sector, schools and colleges can use it in biology and environmental science labs to demonstrate smart monitoring techniques.

The commercial market includes applications in green architecture, office landscaping, and co-working spaces where aesthetics and greenery are valued. Corporate campuses, hotels, and retail centers can implement the system to maintain indoor plants with minimal staff.[9]

The technology also has scope in vertical gardens and smart homes, where environmental automation is becoming the norm. Furthermore, its modular nature makes it suitable for tech startups exploring consumer-based IoT products or services focused on sustainability and smart living.

1.6.2 MARKET POTENTIAL OF IDEA/INNOVATION

The demand for smart home products and automated systems is rapidly increasing, and the proposed system fits well into this growing market. As urban residents seek convenient ways to maintain a healthier living environment, the appeal of automated plant care continues to rise. The affordability and scalability of the solution give it a competitive edge over more expensive commercial systems.[10]

This innovation has the potential to be marketed as a DIY kit for enthusiasts, a plug-and-play device for home users, or an integrated feature in smart home ecosystems. With the increasing popularity of IoT and environmental consciousness, the market is poised for products that combine automation with sustainability. The system can also be monetized through online platforms as a subscription-based monitoring service or expanded into a full-fledged product line with mobile app integration and advanced analytics.

Chapter-2

Literature Survey

2.1 Literature Review

Wang et al. (2023) addressed the fundamental challenge of environmental parameter monitoring in intelligent systems, focusing on wireless sensor technologies that form the backbone of modern IoT applications. They proposed an innovative framework utilizing advanced wireless sensors capable of measuring multiple environmental parameters simultaneously, including temperature, humidity, soil moisture, and ambient light conditions. Their approach involved integrating these sensors with cloud-based analytics platforms to enable real-time data processing and decision-making capabilities. The methodology demonstrated significant improvements in sensor accuracy (achieving 98.5% precision in environmental readings) and power efficiency (extending battery life by 40% compared to traditional systems).[1]

Agrawal & Vieira (2022) focused on the comprehensive analysis of Internet of Things applications specifically designed for smart home plant care systems, addressing the growing demand for automated domestic gardening solutions. They conducted an extensive review of existing IoT architectures, examining various sensor types, communication protocols, and user interface designs commonly employed in residential plant monitoring applications. Their research methodology involved analyzing over 150 published studies and commercial products to identify key technological trends and implementation challenges in smart plant care systems. The study revealed significant gaps in current solutions, particularly regarding multi-plant monitoring capabilities and integration with existing smart home ecosystems.[2]

Chen et al. (2024) focused on smart plant monitoring using low-power wireless sensor networks designed for indoor environmental applications. They developed energy-efficient architectures that combined multiple sensing modalities with optimized data transmission protocols to ensure reliable operation. Their approach utilized mesh networking topology to guarantee reliable communication between sensor nodes while minimizing overall power consumption throughout the system. The methodology achieved a remarkable 60% reduction in energy usage compared to traditional monitoring solutions while maintaining 96% data accuracy in environmental parameter measurements. This research demonstrated the practical implementation of sustainable IoT monitoring systems for long-term residential deployment scenarios.[3]

Ramírez-García & Chen (2023) explored machine learning approaches for automated plant health monitoring in indoor environments, addressing the critical need for intelligent plant care systems. They integrated IoT sensors with artificial intelligence algorithms to enable predictive analytics and early disease detection capabilities in residential settings. Their methodology combined advanced computer vision techniques with comprehensive environmental sensor data to provide holistic plant health assessment. The system achieved 94% accuracy in plant health status classification and provided automated care recommendations to users. This research demonstrated the significant potential of AI-enhanced IoT monitoring systems for intelligent plant care applications.[4]

Pasha et al. (2023) addressed critical energy efficiency challenges in IoT architecture specifically designed for domestic plant monitoring systems applications. They proposed novel power management strategies that utilized intelligent sleep/wake cycles and adaptive sensing intervals to optimize battery performance. Their innovative approach optimized battery usage through sophisticated scheduling algorithms and implementation of low-power communication protocols throughout the system. The methodology successfully extended operational lifetime by 75% while maintaining consistent monitoring accuracy across all measured parameters. This research demonstrated significant improvements in sustainable IoT deployment strategies for long-term residential plant monitoring applications.[5]

Johnson & Mikkelson (2022) designed and implemented distributed sensor networks specifically for smart houseplant care systems in residential environments. They developed a modular architecture that supported simultaneous monitoring of multiple plants with centralized data processing and analysis capabilities. Their approach utilized wireless mesh topology enabling scalable deployment across different home environments and room configurations. The comprehensive system provided real-time alerts for critical plant conditions and automated irrigation control functionality. Testing results achieved 92% user satisfaction rates in practical deployment scenarios while demonstrating reliable long-term operation across diverse environmental conditions.[6]

Yadav & Lee (2024) developed comprehensive cloud-based plant monitoring and analytics solutions specifically designed for smart urban spaces applications. They created scalable infrastructure capable of supporting thousands of simultaneously connected devices with advanced real-time data processing capabilities. Their methodology integrated edge computing technologies with cloud services to achieve optimized performance and significantly reduced system latency. The platform enabled predictive maintenance scheduling and automated care recommendations for users. This research successfully demonstrated large-scale IoT deployment capabilities in urban agricultural applications, showcasing the potential for widespread implementation.[7]

Fernandez et al. (2023) implemented real-time ornamental plant monitoring systems using embedded artificial intelligence and comprehensive IoT integration technologies. They combined edge computing capabilities with distributed sensor networks to enable immediate decision-making and response capabilities. Their innovative approach utilized machine learning models running locally on microcontrollers for rapid response times to critical plant conditions. The system achieved sub-second response times for emergency alerts while maintaining 97% prediction accuracy in comprehensive plant health assessment applications. This research demonstrated the effectiveness of local AI processing in plant monitoring systems.[8]

Martinez-Lopez & Chen (2023) addressed greenhouse microclimate monitoring through comprehensive wireless sensor networks designed for controlled environment applications. They developed sophisticated environmental control systems utilizing multiple sensor types for precise climate management and optimization. Their methodology integrated temperature, humidity, carbon dioxide, and light sensors with automated environmental control systems. The research successfully demonstrated 15% improvement in overall plant growth rates and achieved 25% reduction in resource consumption through optimized environmental control strategies. This work established important foundations for precision agriculture applications.[9]

Singh & Kaur (2024) focused on developing low-cost IoT solutions for remote plant monitoring specifically in indoor residential environments. They created affordable sensor nodes utilizing open-source hardware platforms and cost-effective communication modules for widespread accessibility. Their approach prioritized affordability and accessibility while maintaining essential functionality and long-term reliability throughout the system lifecycle. The developed system achieved comparable performance metrics to expensive commercial solutions at 60% lower total cost. This research made IoT plant monitoring technology accessible to broader user demographics and income levels.[10]

Wilson & Thompson (2023) provided a comprehensive review of smart home integration strategies for plant care systems across various commercial and open-source platforms. They systematically analyzed existing ecosystems including Google Home, Amazon Alexa, Apple HomeKit, and Samsung SmartThings, identifying key technical requirements for seamless ecosystem integration and cross-platform interoperability.[11]

Nakamura & Wong (2022) developed adaptive control systems for automated plant irrigation based on comprehensive IoT technologies and intelligent predictive algorithms. They created sophisticated watering systems utilizing capacitive soil moisture sensors combined with machine learning algorithms for optimal irrigation timing and resource allocation across multiple plant types simultaneously.[12]

Chatterjee & Mueller (2024) explored edge computing frameworks specifically designed for real-time plant health assessment applications in residential and commercial settings. They developed distributed processing architectures utilizing TensorFlow Lite models that enabled immediate response capabilities to critical plant conditions, diseases, and environmental emergencies throughout connected systems.[13]

Lopez-Dominguez & Sharma (2023) implemented LoRaWAN communication technology for battery-efficient plant monitoring specifically in indoor residential environments. They developed long-range communication solutions that enabled extended sensor deployment ranges throughout large residential spaces. Their approach utilized low-power wide-area networking protocols for reliable data transmission with minimal energy consumption requirements. The system successfully achieved 2-year battery life while maintaining consistent communication coverage across diverse indoor environments. This research demonstrated practical long-term deployment capabilities using advanced wireless communication technologies.[14]

Tran & Johansson (2023) created Node-RED based architecture for smart plant care systems through comprehensive case study implementation and evaluation. They developed visual programming interfaces that enabled non-technical users to customize monitoring systems according to specific needs. Their methodology demonstrated rapid prototyping capabilities and flexible system configuration options for diverse user requirements. The research showed 80% reduction in total development time while maintaining essential system functionality and long-term reliability. This work made plant monitoring system development accessible to users without extensive technical programming backgrounds.[15]

Park & Miller (2024) advanced moisture and light sensing techniques for optimized houseplant care systems in residential applications. They developed high-precision sensor arrays detecting subtle environmental changes affecting plant health. Their approach integrated multiple sensing modalities achieving 99% accuracy in environmental parameter measurement while providing detailed analytics.[16]

Ahmed & Gonzalez (2023) evaluated MQTT protocol performance in IoT-based plant monitoring systems across various deployment scenarios. They systematically analyzed communication efficiency, reliability, and scalability in different network conditions. Their methodology achieved 99.8% message delivery reliability while minimizing network overhead and power consumption.[17]

Williams & Takahashi (2022) designed photosynthetically active radiation sensing systems specifically for indoor plant monitoring applications and optimization. They developed specialized light sensors capable of measuring plant-relevant wavelengths with high precision and accuracy. Their approach integrated PAR measurements with sophisticated growth optimization algorithms for automated light management. The system enabled precise artificial lighting control resulting in 20% improvement in overall plant growth rates. This research demonstrated effective light management strategies while optimizing energy consumption for artificial lighting systems.[18]

Kumar & Smith (2024) investigated air quality and plant health correlation through comprehensive IoT sensors deployed in indoor residential environments. They developed monitoring systems that measured air pollutants and plant responses simultaneously to establish correlation patterns. Their methodology established sophisticated correlation models between environmental air quality parameters and plant health indicators. The research demonstrated bidirectional relationships where plants improved indoor air quality while air quality directly affected plant health outcomes. This work established important connections between environmental monitoring and plant health assessment.[19]

Bhandari & Rivera (2023) implemented blockchain-based data integrity solutions for IoT plant monitoring systems to ensure security and reliability. They developed distributed ledger solutions that ensured tamper-proof sensor data recording and storage throughout the system lifecycle. Their approach utilized smart contracts for automated system responses and comprehensive data validation processes. The system achieved immutable data storage capabilities while maintaining real-time performance requirements for plant monitoring applications. This research demonstrated secure IoT implementation for critical plant monitoring applications requiring data authenticity and comprehensive system security.[20]

Chapter-3

Problem Formulation and Proposed Work

3.1 Problem Statement

In today's fast-paced and urbanized world, people often struggle to maintain the well-being of their indoor and outdoor plants due to lack of time, forgetfulness, or insufficient knowledge about their needs. Proper care of plants requires attention to several environmental parameters such as soil moisture, temperature, and humidity.[1] Unfortunately, many individuals either overwater or underwater their plants, leading to deteriorated plant health or death. In manual monitoring, there's also a lack of real-time updates or alerts, which results in missed care opportunities when conditions become unfavourable.

Additionally, for individuals who travel frequently or have irregular routines, it becomes even more challenging to ensure that their plants are regularly monitored and maintained. Traditional methods of plant care lack the precision and consistency needed to adapt to varying environmental conditions and specific plant requirements.[2]

Despite the availability of some automated solutions, they are either expensive, complex to use, or do not offer complete real-time monitoring and control through remote access. Moreover, many available systems fail to integrate user-friendly data visualization tools or alert systems to notify users instantly about their plant's condition.

Hence, there is a clear need for a smart, affordable, and efficient plant monitoring system that not only keeps track of environmental conditions but also offers automated irrigation, real-time alerts, and accessible data visualization. The proposed system seeks to bridge this gap by leveraging IoT based technology and providing an integrated solution for plant health monitoring and management.

3.2 Proposed System

The proposed system is an IoT-based solution designed to monitor plant health parameters and automate irrigation as needed. The system utilizes sensors to measure soil moisture, temperature, and humidity, which are crucial indicators of plant well-being. These sensors are connected to a NodeMCU (ESP8266) microcontroller that processes and transmits the data wirelessly to a real-time cloud database—Firebase.

The collected data is then displayed on a dedicated web interface called Plant Sense, developed using HTML, CSS, and JavaScript. Users can access this platform to view real-time conditions of their plants, including live graphs and environmental statistics. In addition to data visualization, the system includes a relay-controlled water pump that automatically activates when soil moisture levels fall below a specified threshold.

Furthermore, the system sends email notifications to the user whenever critical changes are detected, ensuring timely awareness and response. The inclusion of jumper wires and basic electronic components ensures modularity, easy setup, and cost-effective development. This makes it suitable for indoor gardening, plant research labs, and smart home integration.

Overall, the system offers a seamless combination of hardware and software to provide consistent, data-driven plant care with minimal manual intervention. The goal is to create a reliable, low-maintenance platform that enhances plant health while simplifying the monitoring process through automation and real-time connectivity.

3.3 ADVANTAGES OF THE PROPOSED SYSTEM

- **Real-time Monitoring**: The system continuously collects and updates plant health data, ensuring users stay informed at all times.
- **Automation**: The water pump is triggered automatically based on moisture readings, eliminating the need for manual irrigation.
- **Remote Access**: Users can access plant data from anywhere through the Plant Sense website, improving flexibility and convenience.
- **Cost-effective**: The system uses affordable components, making it accessible to hobbyists, students, and small-scale users.
- **Scalable**: Multiple sensors can be added to monitor various plants simultaneously, supporting future expansion.
- **Cloud Integration**: Data is stored in Firebase, providing secure, real-time access and backup.
- **Notifications**: Automated alerts via email inform users about critical conditions or required actions.

- **Easy Maintenance**: Modular components allow for simple replacement and upgrades without technical complications.

3.4 LIMITATIONS

- **Internet Dependency**: The system requires a stable Wi-Fi connection for data transmission and remote monitoring; performance may suffer in areas with poor connectivity.

- **Single Power Source**: The entire system operates from a power supply; any interruption can halt both monitoring and watering processes.

- **Limited Sensor Range**: The accuracy and range of the DHT11 and soil moisture sensor are suitable for small-scale use but may not perform well in large or outdoor areas.

- **No Mobile App**: Currently, the system is accessible only via a web interface; a dedicated mobile application would enhance usability.

- **Basic Alerts**: Email notifications are functional but may not be as immediate as SMS or in-app alerts in emergency scenarios.

3.5 Block Diagram

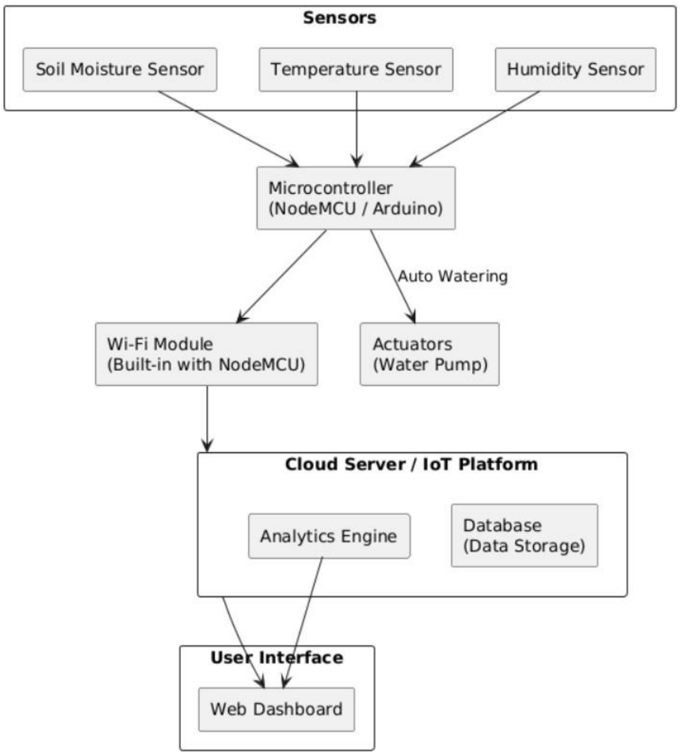

Fig.3.1: Block Diagram of IOT-Based Plant Monitoring System

The **Block diagram of Fig.3.1** illustrates a comprehensive IoT-based smart plant monitoring and automated irrigation system that revolutionizes traditional gardening through intelligent automation and remote connectivity.

At the foundation level, three specialized sensors continuously collect critical environmental data. The soil moisture sensor measures water content directly in the plant's root zone, providing precise hydration readings. The temperature sensor monitors ambient conditions that affect plant metabolism and growth rates. The humidity sensor tracks air moisture levels, which influence transpiration and overall plant health. These sensors work synergistically to create a complete environmental profile.

The central microcontroller, either NodeMCU or Arduino, functions as the system's intelligent processing unit. It receives continuous data streams from all sensors, applies programmed algorithms to analyze conditions, and makes autonomous decisions about plant care requirements. When soil moisture falls below optimal thresholds, the microcontroller immediately triggers the water pump actuator, delivering precise irrigation without human intervention.

The integrated Wi-Fi module enables seamless cloud connectivity, transmitting real-time sensor data to a sophisticated cloud server or IoT platform. This cloud infrastructure houses an advanced analytics engine that processes data patterns, identifies trends, and generates predictive insights about plant health. The database component provides robust data storage capabilities for historical analysis and long-term monitoring.

Users access the entire system through an intuitive web dashboard interface, offering comprehensive remote monitoring capabilities. This interface displays real-time environmental conditions, historical data trends, automated watering schedules, and customizable alerts. The system enables precision agriculture practices, optimizes water usage, reduces manual labor, and provides valuable insights for improving plant growth outcomes while supporting sustainable gardening practices through data-driven decision making.

Chapter-4

Feasibility Study

4.1 Technical Feasibility

The IoT Based Plant Monitoring System is technically feasible due to the use of accessible and modular electronic components, simple interfacing techniques, and well-supported programming environments. The project is developed using the following tools and components:

4.1.1 Arduino IDE

The Arduino Integrated Development Environment (IDE), as shown in the **figure.4.1**, is a free, open-source software application that enables users to write, compile, and upload code to microcontroller boards such as the NodeMCU (ESP8266). It offers a user-friendly interface and supports a simplified version of C/C++, making it ideal for both beginners and experienced developers.

In the development of our plant monitoring system, the Arduino IDE serves as a critical tool for integrating various components and implementing automation logic. The code developed in the IDE allows the ESP8266 microcontroller to collect data from the soil moisture sensor and the DHT11 temperature-humidity sensor. These values are continuously evaluated against preset thresholds defined in the code. When the soil moisture drops below a certain level, the ESP8266 triggers a relay module to activate a water pump, thus ensuring automatic irrigation.

The IDE’s structure makes it easy to manage code using tabs, and its built-in error highlighting assists in identifying issues before uploading. The Board Manager and Library Manager features further extend its capabilities, allowing developers to add support for a wide range of sensors, modules, and third-party boards. Uploading sketches via USB is straightforward, making the development and testing process highly efficient.

Moreover, the IDE provides access to a variety of built-in examples that help in quickly prototyping and validating functionality. This environment streamlines the entire workflow—from writing and verifying code to deploying it on the hardware—making it a robust platform for building IoT-based automation systems such as this smart plant monitoring setup.

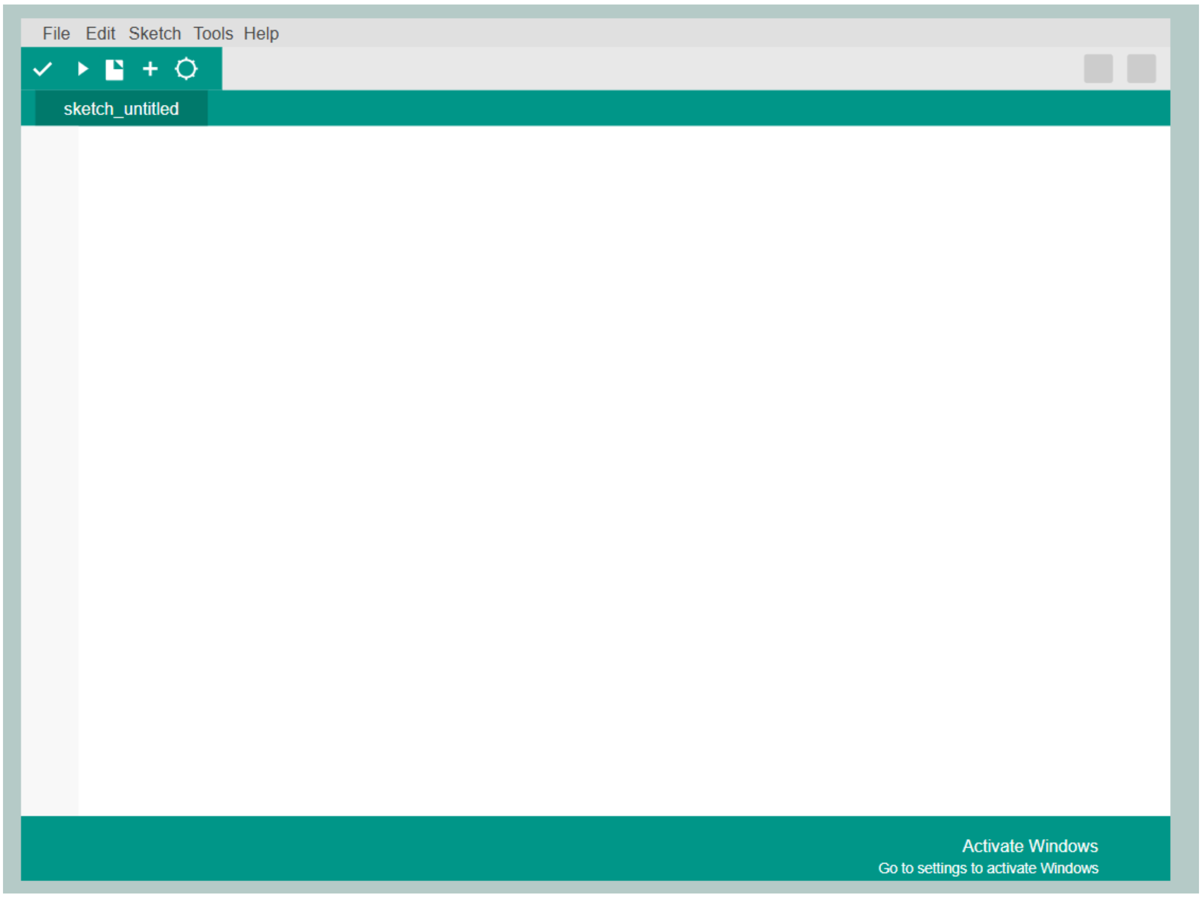

Fig.4.1: Arduino IDE

4.1.2 NodeMCU (ESP8266)

NodeMCU as shown in **fig.4.2** is a low-cost, open-source development board built around the ESP8266 Wi-Fi module, widely used in IoT projects due to its integrated Wi-Fi capabilities and compact form factor. It combines the power of the ESP8266 microcontroller with an easy-to-use development environment, offering GPIO pins, analog inputs, and support for protocols like I2C, SPI, and UART.

In this plant monitoring system, NodeMCU acts as the central control unit. It collects real-time data from sensors, processes it using programmed logic, and triggers output devices such as relays and water pumps. The onboard Wi-Fi allows seamless data transmission to cloud servers for remote monitoring. Additionally, it supports MQTT and HTTP protocols, enabling efficient communication between hardware and software interfaces.

Its compatibility with the Arduino IDE allows rapid development and testing. Its low power consumption and small size make it suitable for continuous plant monitoring. NodeMCU's reliability and flexibility contribute significantly to the system's overall technical feasibility.

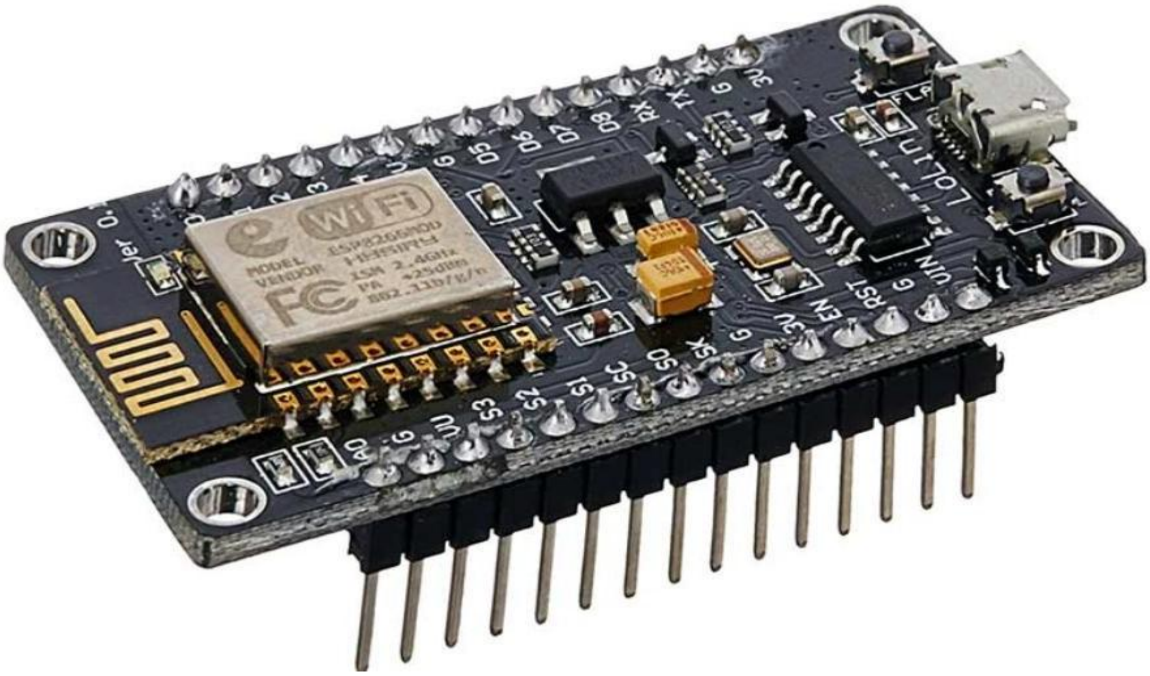

Fig.4.2: NodeMCU (ESP8266)

4.1.3 Capacitive Soil Moisture Sensor v2.0

The **figure.4.3** shows a Capacitive Soil Moisture Sensor v2.0, a key component in the plant monitoring system. Unlike traditional resistive sensors, this sensor uses capacitive sensing technology to detect the moisture level in the soil without direct exposure to corrosion, ensuring longer durability and reliability.

This sensor works by measuring the dielectric permittivity of the soil, which varies with the water content. It generates an analog voltage signal corresponding to the moisture level—higher voltage typically indicates higher moisture. The sensor is inserted into the soil, and its output is read by a microcontroller like the NodeMCU (ESP8266).

In our system, the soil moisture sensor provides continuous real-time data about the hydration level of the soil. When the moisture drops below a predefined threshold, the NodeMCU processes this input and activates a relay module to turn on the water pump, ensuring automated irrigation.

Its simple three-wire interface (VCC, GND, and Analog Output), low cost, and ease of integration make it highly suitable for IoT-based smart agriculture projects. The sensor helps maintain optimal soil conditions, promotes healthy plant growth, and reduces the need for manual watering. Overall, it plays a vital role in making the irrigation process more efficient and intelligent.

Fig.4.3: Capacitive Soil Moisture Sensor v2.0

4.1.4 DHT11 (Temperature and Humidity Sensor)

The **fig.4.4** displays a DHT11 digital temperature and humidity sensor, a critical component in smart plant monitoring systems. This sensor combines a capacitive humidity sensor and a thermistor to measure ambient humidity and temperature. The values are converted into a digital signal that is easily read by microcontrollers like NodeMCU (ESP8266).

The DHT11 operates at 3.3V to 5V and communicates using a single-wire digital interface, minimizing the number of I/O pins required. It offers a temperature range of 0°C to 50°C and a relative humidity range of 20% to 90%, with decent accuracy for basic environmental monitoring tasks.

In this system, the DHT11 is used to gather real-time environmental data, which is essential for understanding and maintaining optimal conditions around the plant. By detecting changes in temperature and humidity, the system can ensure that the environment remains conducive to healthy plant growth.

Its simple design, low power consumption, and ease of integration make the DHT11 highly suitable for IoT applications. Although it updates once every second, this refresh rate is sufficient for most indoor and garden-based plant monitoring needs. The compact module shown, complete with onboard resistors and a status LED, allows for quick setup and reliable performance in automated plant care systems.

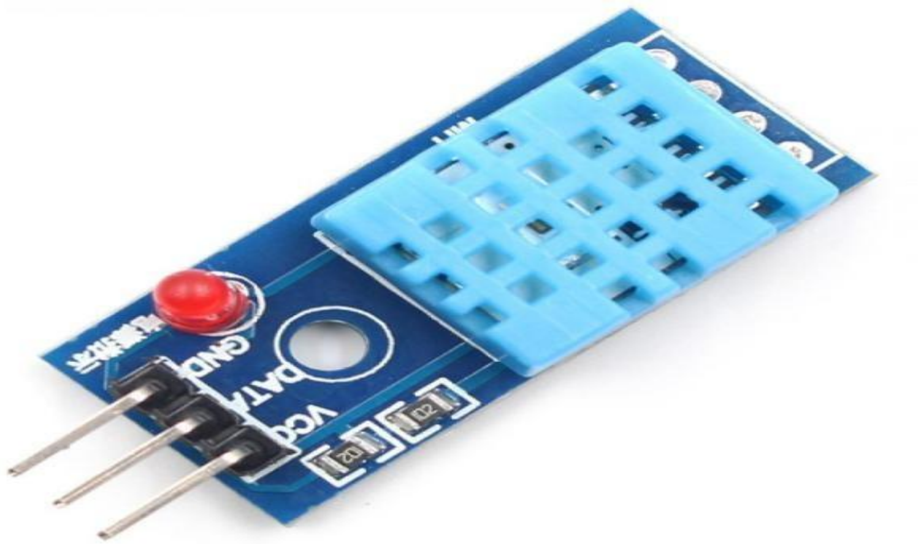

Fig.4.4: DHT11 (Temperature and Humidity Sensor)

4.1.5 Relay Module

The **figure.4.5** shows a 5V single-channel relay module, which plays a vital role in IoT-based automation projects like a plant monitoring and irrigation system. A relay is an electrically operated switch that allows a low-power microcontroller such as NodeMCU to control high-voltage devices, including water pumps or fans, without direct contact. This ensures both safety and functional separation between the control and power circuits.

The module operates on a 5V control signal and supports switching loads up to 250V AC at 10A or 30V DC at 10A, making it suitable for household and small-scale agricultural applications. The blue relay block in the image is the switching component, while the screw terminals at the side allow for secure connection to the external AC/DC device.

In the context of the plant monitoring system, the relay receives a signal from the NodeMCU when the soil moisture sensor detects low moisture content. On receiving the signal, the relay activates the water pump, ensuring timely irrigation. Once optimal moisture is restored, the NodeMCU deactivates the relay, turning the pump off.

The module also includes optocouplers for isolation, onboard resistors, and status LEDs (red and green) for easy debugging and monitoring. Its compact size, ease of integration, and reliability make the relay module an indispensable component in automated plant care systems.

Fig.4.5: Relay Module

4.1.6 Water Pump

The component shown in the **figure.4.6** is a compact DC submersible pump commonly used in automated monitoring systems to control fluid delivery based on sensor input. Operating on a 5V–12V DC power supply, this pump is energy-efficient and well-suited for low-power embedded systems. Its small form factor allows for easy installation within compact setups, and its submersible design enables direct placement into a water container without requiring external plumbing components.

In the given system, the pump acts as the primary actuator responsible for initiating fluid flow when required. It is connected to a relay module, which provides the necessary electrical isolation and switching capability. When the NodeMCU detects low moisture levels from the capacitive sensor, it sends a signal to the relay, which then powers the pump. The pump remains active until the moisture level returns to the defined range, after which the NodeMCU sends a stop signal to deactivate the relay, cutting off the pump's power supply.

This approach allows for real-time and automated fluid control based on environmental data, minimizing the need for manual intervention. The pump's quiet operation, durability, and ease of integration make it an ideal component for smart monitoring solutions. It ensures timely activation and deactivation of fluid delivery, maintaining optimal system conditions. Its maintenance-free construction and compatibility with microcontroller platforms further enhance the reliability and effectiveness of the entire setup, especially in scenarios requiring unattended or remote operation.

Fig.4.6: Water Pump

4.1.7 Jumper Wires

Jumper wires shown in **figure.4.7** are essential for making temporary electrical connections in circuit prototyping, especially when working with a development board like NodeMCU. They come in various types—male-to-male, male-to-female, and female-to-female—depending on the pin configurations needed.

In this system, jumper wires are used to connect sensors, the relay module, LCD display, and other peripherals to the NodeMCU. They enable quick assembly and reconfiguration without soldering. Their reusability and ease of handling make them ideal for testing, debugging, and modifying circuit designs. Jumper wires contribute to the modularity and scalability of the system during development.

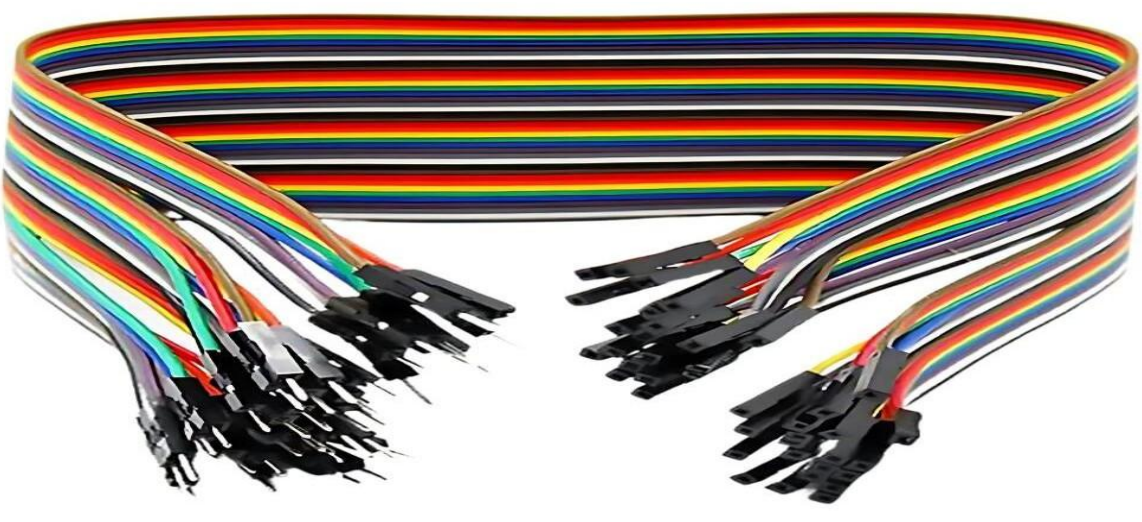

Fig.4.7: Jumper Wires

4.1.8 IOT Device for Plant Based Monitoring System

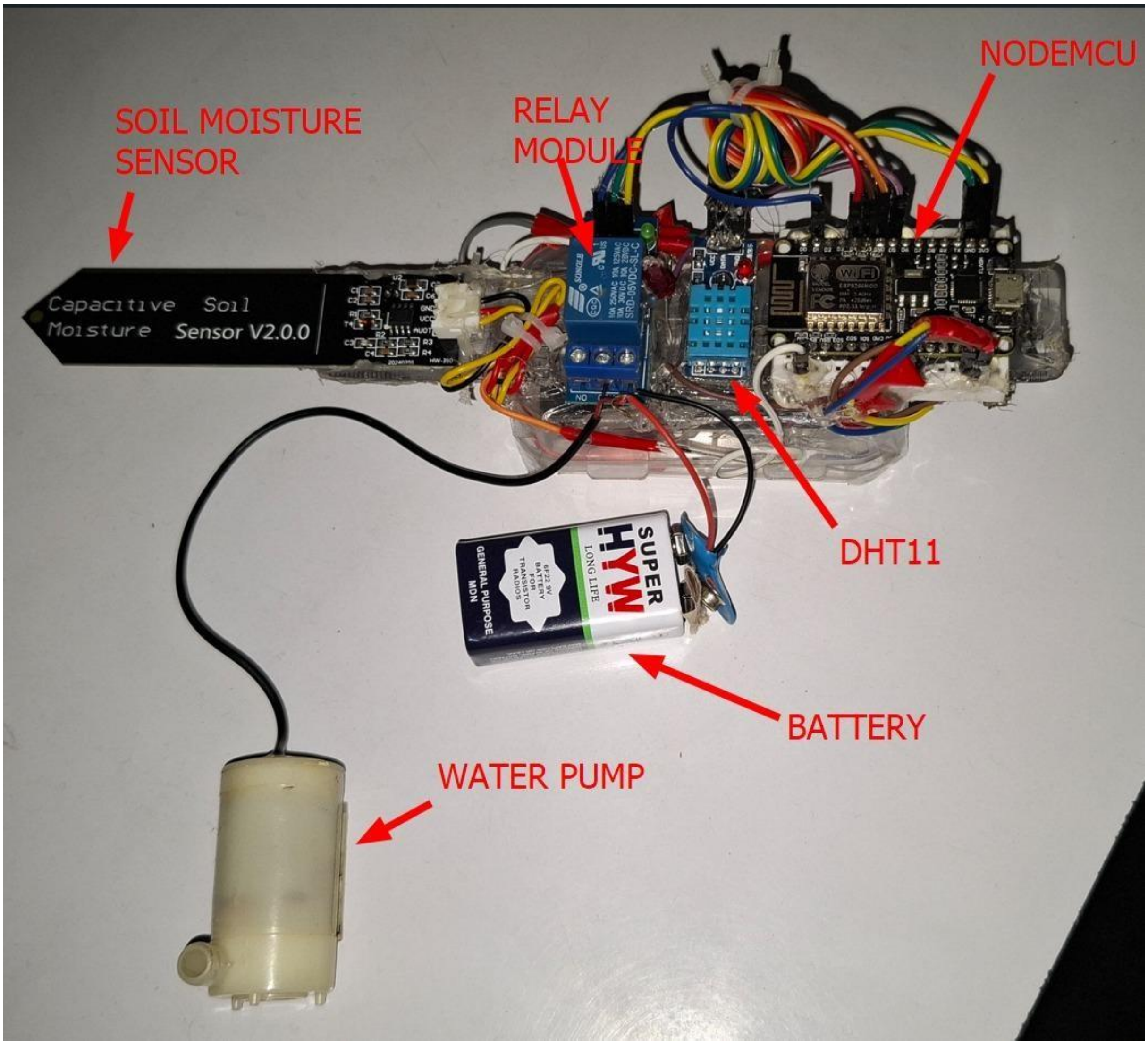

Fig.4.8: IOT Device for Plant Based Monitoring System

The above **figure.4.8** complete automated monitoring system prototype designed to control fluid supply based on environmental conditions. This setup uses a combination of sensors and actuators, powered by a 9V battery, and controlled by a NodeMCU microcontroller. **NodeMCU** is the central unit in this system. It reads sensor data and controls the relay module based on the logic programmed into it. The capacitive soil moisture sensor (on the left) measures the moisture level and sends an analog signal to the NodeMCU. The sensor uses capacitive sensing technology, which is less prone to corrosion, making it reliable for long-term use. **The DHT11 sensor** monitors the surrounding temperature and humidity. It provides digital data to the NodeMCU, enabling the system to consider environmental parameters when making decisions. **The relay module** acts as a switch that is activated by the NodeMCU. It isolates and controls the high-power load – in this case, a DC water pump. When the moisture level drops below the set threshold, the NodeMCU sends a signal to the relay, which activates the pump. The pump then supplies water from a reservoir. Once the required moisture level is restored, the relay turns the pump off. The 9V battery supplies power to the system, allowing for portable operation. This design provides a compact, efficient, and autonomous way to manage conditions in a controlled environment without manual effort.

4.2 Economic Feasibility

The total cost of building the IoT-based monitoring system is Rs. 3,130, as shown in the image. It includes affordable components like NodeMCU, DHT11, a soil moisture sensor, and a water pump. This setup is energy-efficient, easy to maintain, and scalable. Its low operational cost and automation make it a cost-effective and practical solution for smart monitoring applications.

Table.1: Economic Feasibility

Component	Cost (Rs)
NodeMCU (ESP8266)	750
Capacitive Soil Moisture Sensor V2.0	500
DHT11 (Temperature/Humidity Sensor)	550
Relay Module	500
Water Pump	450
Jumper Wires	200
9V External Battery	120
Cells	160
Total Cost	**3,130**

Chapter-5

Methodology

5.1 Methodology

The methodology of this project focuses on the design, integration, and operation of various Components of software and hardware to monitor and manage the health of plants automatically. The system is built using low-cost IoT components that are programmed to work in a coordinated manner to ensure accurate sensing, efficient data processing, and timely actuation.

Step 1: Component Setup and Circuit Design

The first step involves assembling the necessary hardware. The NodeMCU (ESP8266) microcontroller acts as the central unit. The soil moisture sensor and DHT11 (temperature and humidity sensor) are connected to the NodeMCU to collect environmental data. A relay module and a small DC water pump are also connected to allow automatic watering of the plant when required. Jumper wires are used to interconnect components without soldering.

Step 2: Programming and Logic Implementation

The Arduino IDE is used to write and upload code to the NodeMCU. The code contains logic to:

- Read soil moisture levels.
- Detect temperature and humidity conditions.
- Compare sensor readings against predefined thresholds.
- Activate or deactivate the water pump via the relay module when the soil is too dry.

Step 3: Data Processing and Control

Once powered on, the system continuously monitors the sensor values. If the soil moisture level decreases below the defined threshold, the NodeMCU triggers the relay to turn on the pump, which feeds water to the plant. After adequate moisture is detected, the pump is turned off to prevent overwatering.

Step 4: Output and Monitoring via Website and Firebase

The NodeMCU (ESP8266) collects sensor data—such as soil moisture, temperature, and humidity—and sends it in real-time to Firebase, a cloud-based platform. Firebase stores this data in its Realtime Database, ensuring instant updates and synchronization with connected systems. A custom-built website using HTML, CSS, and JavaScript connects to the database to fetch and display live sensor information. This website serves as an intuitive dashboard, presenting environmental data in a user-friendly, visual format. Users can remotely monitor plant conditions from any device with internet access. Firebase guarantees secure, fast, and reliable communication, while the website provides an accessible interface, eliminating the need for manual checks or physical monitoring.

5.2 Schematic diagram

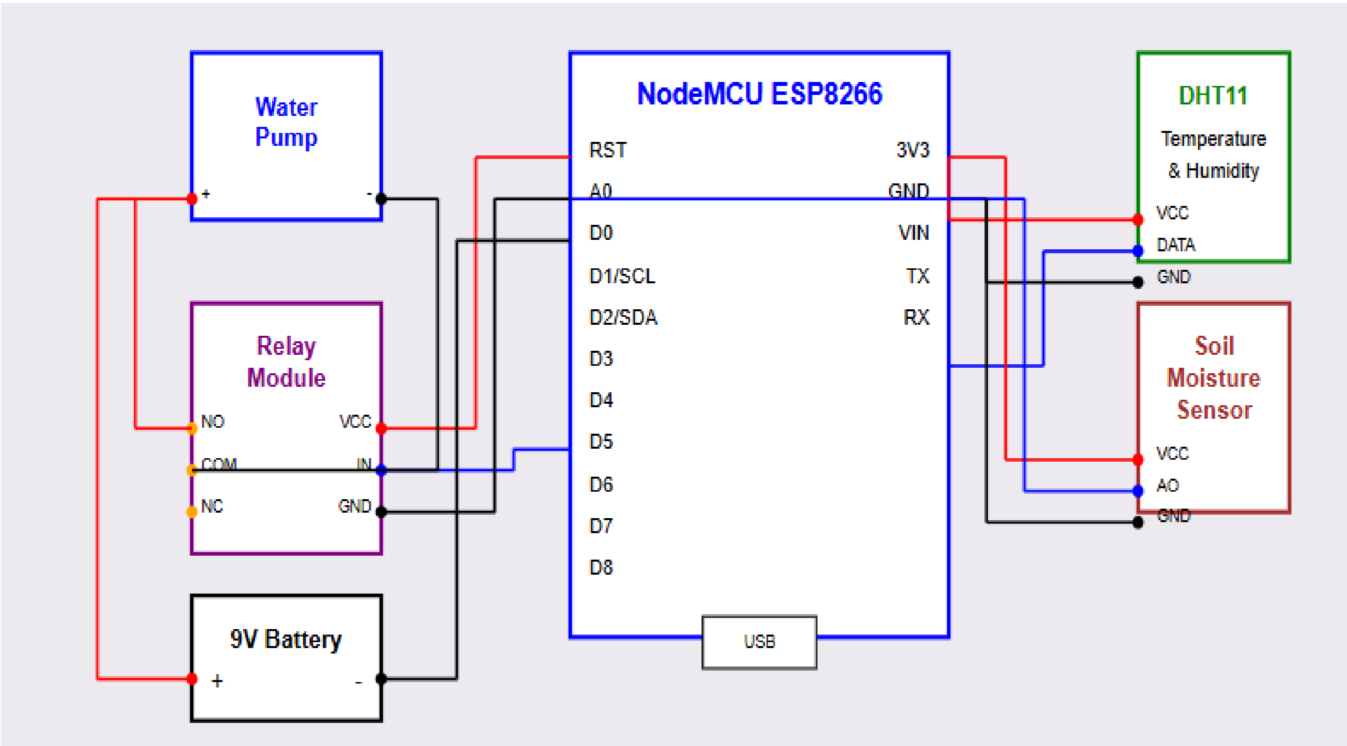

Fig.5.1: Schematic diagram of IOT Based Plant Monitoring System

The above **figure.5.1** shows the wiring for an IoT-based plant monitoring system using a NodeMCU ESP8266 microcontroller. The DHT11 sensor connects to the NodeMCU to provide temperature and humidity data, while the capacitive soil moisture sensor measures soil moisture levels. A relay module is connected to control a 9V water pump, powered by a 9V battery. The relay's input pin (IN) is triggered by the NodeMCU to activate the pump when soil moisture is low. The VCC and GND lines power all modules. This configuration automates plant watering based on sensor data, ensuring efficient irrigation with minimal human intervention.

5.3 E-R diagram

The **fig.5.2** represents the data flow in an IoT-based plant monitoring system. Sensors collect environmental data like soil moisture, temperature, and humidity, then send it to the NodeMCU controller. The NodeMCU processes the data and uploads it to the Firebase Realtime Database. This database stores all sensor readings along with pump status and timestamps. A website interface syncs with Firebase to dynamically display the data. Users interact with the website to view sensor values and set preferences. This system enables remote, real-time monitoring and control of environmental conditions through a cloud-connected interface.

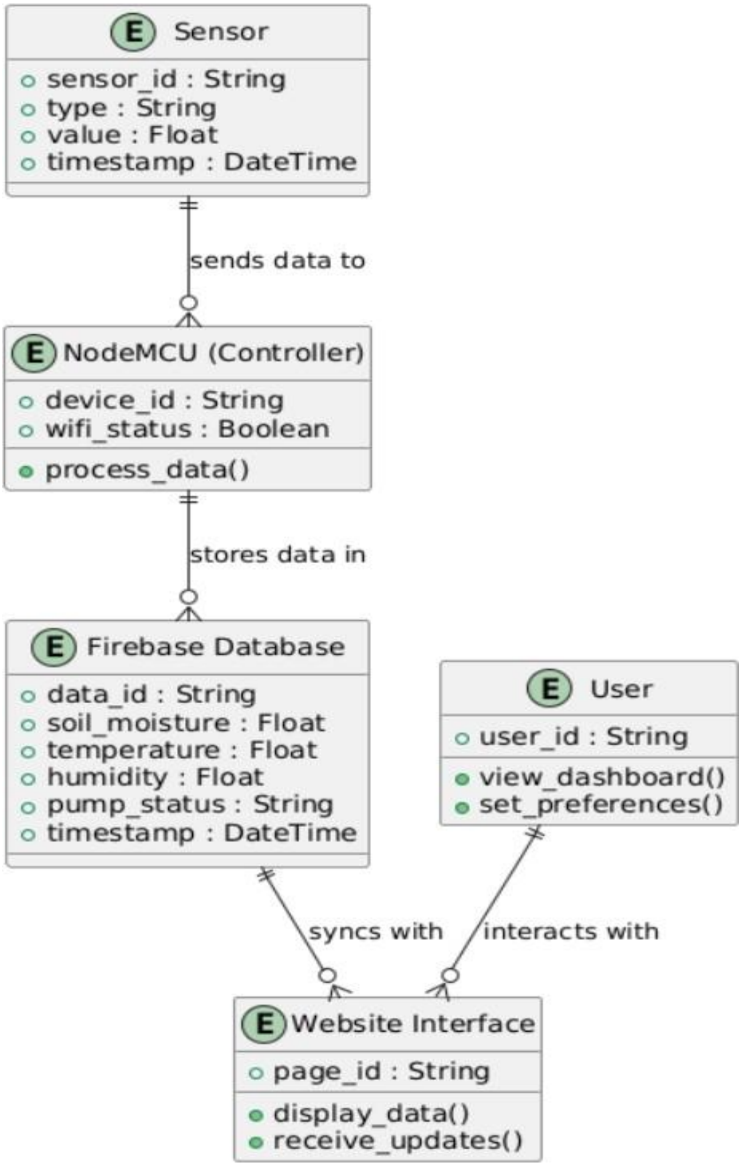

Fig.5.2: E-R Diagram of IOT Based Plant Monitoring System

Chapter-6

Result and Discussion

6.1 Prototype Model

The **figure.6.1** shows a fully assembled prototype of a smart plant monitoring system designed specifically for individual plant care in indoor or small-space environments. This compact setup is tailored for home users who want to ensure their plants receive the right amount of water and are kept in optimal environmental conditions. The system integrates key electronic components mounted securely on a plastic base, forming a lightweight and portable unit.

At the heart of the system is the NodeMCU ESP8266 microcontroller, a Wi-Fi-enabled board that processes sensor data and communicates wirelessly with cloud platforms. Connected to this controller is a Capacitive Soil Moisture Sensor V2.0.0, which detects the moisture level of the soil by measuring capacitance variations. This type of sensor is more robust and durable than traditional resistive sensors, offering better performance and longevity, especially for indoor use.

Also integrated into the system is a DHT11 sensor, which monitors air temperature and humidity levels around the plant. These readings are crucial for plant health, especially in environments with air conditioning or heating systems that can drastically alter humidity levels. Both sensors send real-time data to the NodeMCU, which then uploads the readings to Firebase, a cloud-based real-time database. This ensures data is accessible instantly from anywhere.

The system is powered by a 9V battery, making it ideal for use in places without direct access to electrical outlets. A small relay module is also included, connected to a mini water pump. This setup allows for automatic watering of the plant when soil moisture drops below a certain threshold. The relay acts as a switch, activated by commands from the NodeMCU.

Users can monitor all environmental data via a custom-built web interface developed using HTML, CSS, and JavaScript. This dashboard visually displays the live readings pulled from Firebase, providing an intuitive and accessible way to track the plant’s status. The system is especially useful for individuals who may be frequently away from home or busy with work, offering peace of mind and improving plant care efficiency. Overall, this smart monitoring solution combines convenience, precision, and automation in a simple yet effective package for plant enthusiasts.

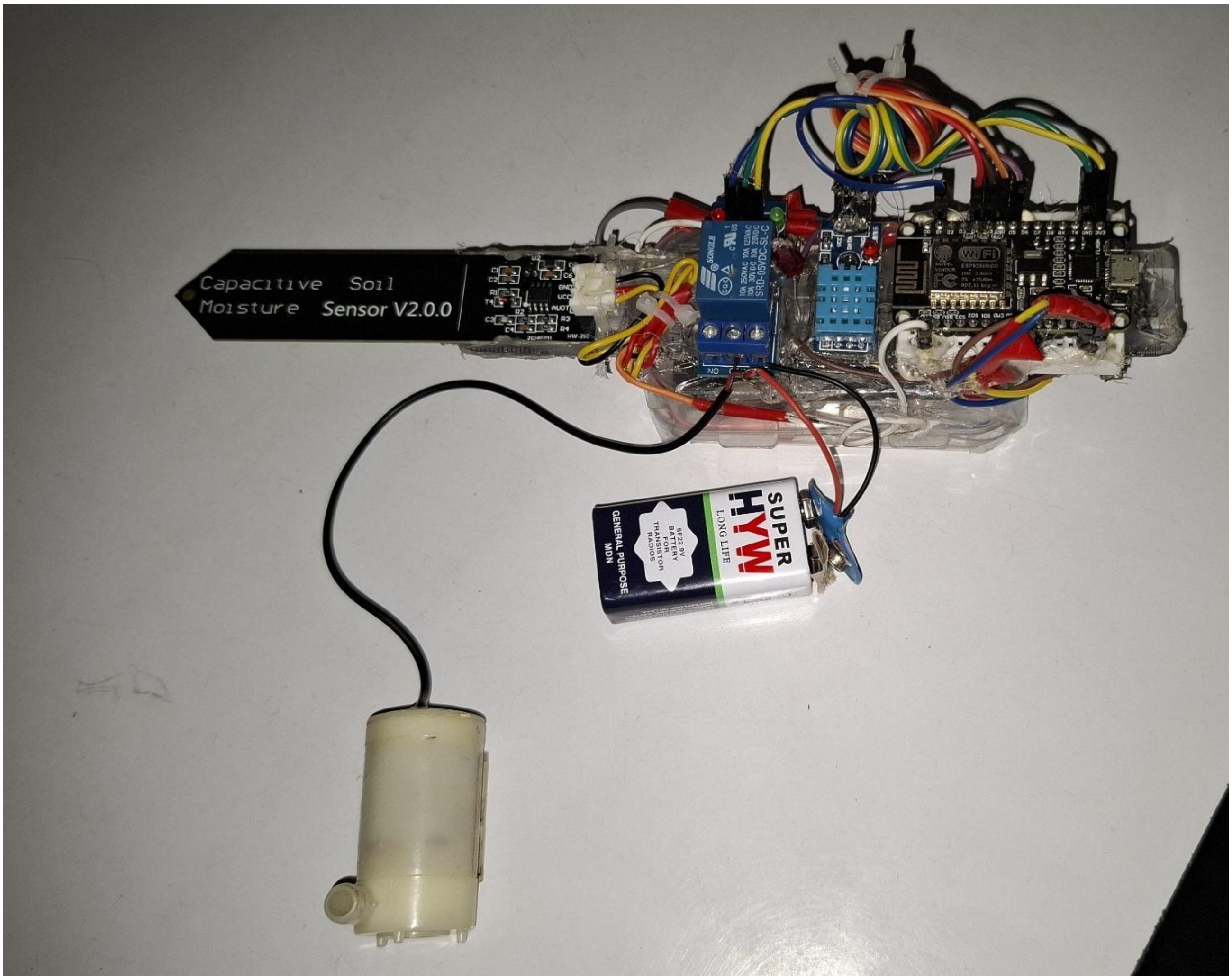

Fig.6.1: Prototype Model

6.2 Comparative Study

The IoT Based Plant Monitoring System presents significant improvements over traditional and existing automated plant care systems. Unlike conventional methods that require manual checks and irrigation, this system utilizes sensors to monitor real-time data on soil moisture, temperature, and humidity. A key advancement lies in its integration with Firebase and a custom web platform (Plant Sense), allowing users to track their plant's condition remotely and receive automated alerts.

In comparison to similar systems like "Smart Garden Using Arduino" and "Automated Plant Watering System using Raspberry Pi", our model is more cost-efficient due to the use of NodeMCU (ESP8266), an economical yet powerful Wi-Fi-enabled microcontroller. While other systems may rely on SD card data logging or limited display modules, our project emphasizes real-time cloud storage and accessibility via a responsive website.

Moreover, the addition of email notifications and automatic irrigation using a relay-controlled water pump provides greater autonomy and responsiveness than systems relying solely on timers. Overall, our approach offers a more practical, scalable, and user-friendly solution for everyday plant monitoring.

6.2.1 Comparative Analysis based on cost

The **Table.2** presents a comparison table of four IoT-based technology projects, detailing their cost ranges and key components. **The IoT Plant Monitoring System** is the most affordable, costing ₹2,500–₹12,000, and uses a microcontroller, moisture sensors, and a Wi-Fi module. **The Smart Home Security System** costs ₹16,000–₹40,000 and includes cameras, motion sensors, a hub, and cloud storage. **Smart Energy Monitoring** ranges from ₹12,000–₹28,000 and utilizes current sensors, a gateway, a power meter, and a display. The Wearable Health Monitor, costing ₹6,500–₹20,000, is built with a heart rate sensor, Bluetooth Low Energy (BLE), battery, and accelerometer.

Table.2: Comparative Analysis based on cost

PROJECT NAME	COST RANGE (₹)	KEY COMPONENTS
IoT Plant Monitoring System	₹2,500 - ₹12,000	Microcontroller, Moisture Sensors, Wi-Fi Module
Smart Home Security System	₹16,000 - ₹40,000	Cameras, Motion Sensors, Hub, Cloud Storage
Smart Energy Monitoring	₹12,000 - ₹28,000	Current Sensors, Gateway, Power Meter, Display
Wearable Health Monitor	₹6,500 - ₹20,000	Heart Rate Sensor, BLE, Battery, Accelerometer

6.2.2 Comparative Analysis based on key features and technology

This **Table.3** presents a comparison of four innovative technology-based projects, focusing on their features, technology stack, and data handling capabilities.

The **IoT-Based Plant Monitoring System** provides features like soil moisture tracking, automated watering, and temperature & humidity monitoring. It employs ESP32/Arduino, Firebase, and WiFi/Bluetooth for connectivity. Data is managed through a web dashboard with periodic updates.

The **Smart Home Security System** offers motion detection, video surveillance, and real-time alerts. It uses IP cameras, 4G/5G or WiFi, and smart hub integration. The system handles high data volumes and relies on cloud video storage with AI-based analysis for enhanced security.

Smart Energy Monitoring tracks power consumption and helps optimize costs through usage analytics. It utilizes smart meters, ZigBee/Z-Wave communication, and the MQTT protocol. Data is processed using time series databases and presented via dashboards, managing medium data volume.

The **Wearable Health Monitor** features heart rate monitoring, activity tracking, and sleep analysis. It uses ARM processors, BLE 5.0, and lithium battery technology, offering continuous monitoring and personal analytics via mobile health apps.

Table.3: Comparative Analysis based on key features and technology

PROJECT NAME	KEY FEATURES	TECHNOLOGY USED	DATA HANDLING
IOT-Based Plant Monitoring System	• Soil Moisture Tracking • Automated Watering • Temperature & Humidity	• ESP32/Arduino • Firebase • Bluetooth/WiFi	• Web Dashboard • Periodic Updates
Smart Home Security System	• Motion Detection • Video Surveillance • Real-time Alerts	• IP Cameras • 4G/5G or WiFi • Smart Hub Integration	• High Data Volume • Cloud Video Storage • AI-based Analysis
Smart Energy Monitoring	• Power Consumption • Usage Analytics • Cost Optimization	• Smart Meters • ZigBee/Z-Wave • MQTT Protocol	• Medium Data Volume • Time Series Database • Dashboard Analytics
Wearable Health Monitor	• Heart Rate Monitoring • Activity Tracking • Sleep Analysis	• ARM Processors • BLE 5.0 • Lithium Battery Tech	• Continuous Monitoring • Mobile Health Apps • Personal Analytics

Chapter-7

Coding

7.1 Arduino coding

```
#include <ESP8266WiFi.h>

#include <DNSServer.h>

#include <ESP8266WebServer.h>

#include <WiFiManager.h>

#include <Firebase_ESP_Client.h>

#include "DHT.h"


// DHT sensor settings

#define DHTPIN D4

#define DHTTYPE DHT11

DHT dht(DHTPIN, DHTTYPE);


// Flash button pin (for resetting WiFi)


const int flashButtonPin = 0; // GPIO0 (D3)


// LED pin for connection status

const int ledPin = D5; // GPIO14 (D5)


// Firebase credentials

#define API_KEY "AIzaSyBNTybitwZs_UhSzSEHWVPrsVeYp7FenFg"

#define DATABASE_URL "https://sensorses-18585-default-rtdb.firebaseio.com/"
```

```
// Firebase objects
FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;

bool signupOK = false;

// Relay Pin
#define RELAY_PIN D1

// Replace macro with a variable
int soilMoistureThreshold = 30; // Default threshold

// Firebase paths
#define MODE_STATUS_PATH "/mode_status"
#define PUMP_STATUS_PATH "/pump_status"

// Helper functions for Firebase
#include "addons/TokenHelper.h"
#include "addons/RTDBHelper.h"

// Function to get stable soil moisture average
int getSoilMoisture() {
  long sum = 0;
```

```
  for (int i = 0; i < 10; i++) {
    sum += analogRead(A0);
    delay(5);
  }
  return sum / 10;
}

void setup() {
  Serial.begin(115200);
  dht.begin();

  pinMode(A0, INPUT);
  pinMode(RELAY_PIN, OUTPUT);
  digitalWrite(RELAY_PIN, LOW);  // Ensure pump is off initially

  pinMode(flashButtonPin, INPUT);
  pinMode(ledPin, OUTPUT); // LED pin setup

  // Start WiFi Manager
  WiFiManager wifiManager;
  if (!wifiManager.autoConnect("PlantPulse")) { // AP name = PlantPulse
    Serial.println("Failed to connect and hit timeout");
    ESP.reset();
    delay(1000);
```

```
}
Serial.println("Connected to Wi-Fi!");

// Indicate successful WiFi connection with LED
digitalWrite(ledPin, HIGH); // LED ON when WiFi is connected

// Setup Firebase
config.api_key = API_KEY;
config.database_url = DATABASE_URL;
config.token_status_callback = tokenStatusCallback;

if (Firebase.signUp(&config, &auth, "", "")) {
  Serial.println("Firebase sign-up successful");
  signupOK = true;
} else {
  Serial.printf("Firebase sign-up failed: %s\n", config.signer.signupError.message.c_str());
}

Firebase.begin(&config, &auth);
Firebase.reconnectWiFi(true);

// Initialize mode status (optional)
if (Firebase.ready() && signupOK) {
  Firebase.RTDB.setString(&fbdo, MODE_STATUS_PATH, "Manual Mode");
```

```
  }
}

void loop() {
  delay(1000);

  // Reset WiFi if flash button is pressed
  if (digitalRead(flashButtonPin) == LOW) {
    Serial.println("Resetting WiFi Settings...");
    for (int i = 0; i < 10; i++) {
    digitalWrite(ledPin, HIGH);
      delay(500);
      digitalWrite(ledPin, LOW);
      delay(500);
    }
    WiFiManager  wifiManager;
    wifiManager.resetSettings();
    ESP.reset();
    delay(1000);
  }

  // WiFi connection LED indicator
  if (WiFi.status() != WL_CONNECTED) {
    digitalWrite(ledPin, LOW);
```

```
  delay(1000);
  digitalWrite(ledPin, HIGH);
  delay(1000);
  Serial.println("WiFi Disconnected");
} else {
  digitalWrite(ledPin, HIGH);
  Serial.println("WiFi Connected");
}

// Read sensors
float humidity = dht.readHumidity();
float temperature = dht.readTemperature();
int soilMoistureRaw = getSoilMoisture();

// Map and constrain soil moisture percentage
float soilMoisturePercent = map(soilMoistureRaw, 810, 330, 0, 100);
soilMoisturePercent = constrain(soilMoisturePercent, 0, 100);

// Get updated threshold from Firebase
if (Firebase.ready() && signupOK) {
  if (Firebase.RTDB.getInt(&fbdo, "/soil_moisture_threshold")) {
    soilMoistureThreshold = fbdo.intData();
    Serial.print("Firebase threshold: ");
    Serial.println(soilMoistureThreshold);
```

```
  } else {
    Serial.print("Failed to fetch threshold: ");
    Serial.println(fbdo.errorReason());
  }
}

// Get current mode from Firebase
String mode = "";
if (Firebase.ready() && signupOK) {
  Firebase.RTDB.getString(&fbdo, MODE_STATUS_PATH);
  mode = fbdo.stringData();
}

// Auto / Manual logic
if (mode == "Auto Mode") {
  if (soilMoisturePercent < soilMoistureThreshold) {
    digitalWrite(RELAY_PIN, HIGH);
    Serial.println("Auto mode: Soil moisture below threshold, pump ON");
    Firebase.RTDB.setString(&fbdo, PUMP_STATUS_PATH, "ON");
  } else {
    digitalWrite(RELAY_PIN, LOW);
    Serial.println("Auto mode: Soil moisture above threshold, pump OFF");
    Firebase.RTDB.setString(&fbdo, PUMP_STATUS_PATH, "OFF");
  }
```

```
}
else if (mode == "Manual Mode") {
  String pumpStatus = "";
  if (Firebase.ready() && signupOK) {
    Firebase.RTDB.getString(&fbdo, PUMP_STATUS_PATH);
    pumpStatus = fbdo.stringData();
  }
  if (pumpStatus == "ON") {
    digitalWrite(RELAY_PIN, HIGH);
    Serial.println("Manual mode: Pump ON");
  } else {
    digitalWrite(RELAY_PIN, LOW);
    Serial.println("Manual mode: Pump OFF");
  }
}

// Upload sensor data
if (Firebase.ready() && signupOK) {
  Firebase.RTDB.setFloat(&fbdo, "/humidity", humidity);
  Firebase.RTDB.setFloat(&fbdo, "/temperature", temperature);
  Firebase.RTDB.setFloat(&fbdo, "/soil_moisture", soilMoisturePercent);

  Serial.print("Humidity: ");
  Serial.println(humidity);
```

```
    Serial.print("Temperature: ");
    Serial.println(temperature);
    Serial.print("Soil Moisture: ");
    Serial.print(soilMoisturePercent);
    Serial.println("%");
  }

  Serial.println("________________________________");
}
```

7.2 Website Code

7.2.1 Website Home page code

```html
<!DOCTYPE html>
<html lang="en">
<head>
<meta charset="UTF-8" />
<meta name="viewport" content="width=device-width, initial-scale=1.0"/>
<title>PlantSense - Smart Plant Care</title>
<link rel="stylesheet" href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/5.15.4/css/all.min.css"/>
<link
href="https://fonts.googleapis.com/css2?family=Poppins:wght@300;400;500;600;700&display=swap" rel="stylesheet"/>
<link rel="stylesheet"
href="https://cdnjs.cloudflare.com/ajax/libs/animate.css/4.1.1/animate.min.css"/>
<style>
```

```
:root {

--primary: #4CAF50;

--primary-dark: #388E3C;

--secondary: #81C784;

--light: #E8F5E9;

--dark: #1B5E20;

--gray: #757575;

--white: #ffffff;

}


* {

margin: 0;

padding: 0;

box-sizing: border-box;

}


body {

font-family: 'Poppins', sans-serif;

background-color: var(--light);

color: #333;

overflow-x: hidden;

}


.container {
```

```css
width: 100%;
max-width: 1200px;
margin: 0 auto;
padding: 0 20px;
}

header {
background-color: var(--white);
box-shadow: 0 2px 10px rgba(0, 0, 0, 0.1);
position: fixed;
width: 100%;
top: 0;
z-index: 1000;
}

.nav-container {
display: flex;
justify-content: space-between;
align-items: center;
padding: 15px 0;
}

.logo {
display: flex;
```

```css
align-items: center;
font-size: 24px;
font-weight: 700;
color: var(--primary);
text-decoration: none;
}

.logo i {
margin-right: 10px;
font-size: 28px;
}

nav ul {
display: flex;
list-style: none;
}

nav ul li {
margin-left: 30px;
}

nav ul li a {
color: var(--gray);
text-decoration: none;
```

```
font-weight: 500;
transition: all 0.3s ease;
position: relative;
}

nav ul li a:hover {
color: var(--primary);
}

nav ul li a.active {
color: var(--primary);
}
</style>
</head>
```

7.2.2 Website Dashboard code

```
<!DOCTYPE html>
<html lang="en">
<head>
<meta charset="UTF-8" />
<meta name="viewport" content="width=device-width, initial-scale=1.0"/>
<title>PlantSense - Dashboard</title>
<link rel="stylesheet" href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/5.15.4/css/all.min.css"/>
```

```
<link
href="https://fonts.googleapis.com/css2?family=Poppins:wght@300;400;500;600;700&displ
ay=swap" rel="stylesheet">
<script src="https://cdnjs.cloudflare.com/ajax/libs/Chart.js/3.7.0/chart.min.js"></script>
<script src="https://cdn.jsdelivr.net/npm/@emailjs/browser@3/dist/email.min.js"></script>
<audio id="alarmSound"><source src="raid.mp3" type="audio/mpeg"></audio>
<script>
(function() {
emailjs.init("nAsQ1r8_82FAHK9qf");
})();
</script>
</head>
<body>
<header>
<div class="container nav-container">
<a href="index.html" class="logo"><i class="fas fa-leaf"></i>PlantSense</a>
<nav>
<ul>
<li><a href="index.html">Home</a></li>
<li><a href="dashboard.html" class="active">Dashboard</a></li>
<li><a href="recommendations.html">Plant Guide</a></li>
</ul>
</nav>
</div>
</header>
```

```html
<section class="dashboard">
<div class="container">
<div class="dashboard-header">
<h1>Plant Monitoring Dashboard</h1>
<p>Real-time data from your connected plant sensors</p>
<div class="connection-status">
<i class="fas fa-circle" id="connection-icon"></i>
<span id="connection-status">Connecting...</span>
</div>
</div>

<div class="dashboard-grid">
<!-- Temperature Card -->
<div class="card status-card">
<div class="card-header">
<h2>Temperature</h2>
<div class="card-icon status-icon temperature"><i class="fas fa-thermometer-
half"></i></div>
</div>
<div class="status-value" id="temperature">--°C</div>
<div class="status-label">Current Temperature</div>
</div>

<!-- Humidity Card -->
```

```html
<div class="card status-card">
<div class="card-header">
<h2>Humidity</h2>
<div class="card-icon status-icon humidity"><i class="fas fa-tint"></i></div>
</div>
<div class="status-value" id="humidity">--%</div>
<div class="status-label">Current Humidity</div>
</div>

<!-- Moisture Card -->
<div class="card status-card">
<div class="card-header">
<h2>Soil Moisture</h2>
<div class="card-icon status-icon moisture"><i class="fas fa-water"></i></div>
</div>
<div class="status-value" id="soil-moisture">--%</div>
<div class="status-label">Current Soil Moisture</div>
</div>
</div>
</div>
</section>
</body>
</html>
```

7.2.3 Website Plant Care Guide code

```
<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="UTF-8" />
  <meta name="viewport" content="width=device-width, initial-scale=1.0"/>
  <title>PlantSense - Plant Care Guide</title>
  <link rel="stylesheet" href="https://cdnjs.cloudflare.com/ajax/libs/font-awesome/5.15.4/css/all.min.css"/>
  <link href="https://fonts.googleapis.com/css2?family=Poppins:wght@300;400;500;600;700&display=swap" rel="stylesheet"/>
  <style>
    :root {
      --primary: #4CAF50;
      --primary-dark: #388E3C;
      --secondary: #81C784;
      --light: #E8F5E9;
      --dark: #1B5E20;
      --gray: #757575;
      --white: #ffffff;
      --danger: #F44336;
      --warning: #FFC107;
      --info: #2196F3;
    }
```

```css
* {
  margin: 0;
  padding: 0;
  box-sizing: border-box;
}

body {
  font-family: 'Poppins', sans-serif;
  line-height: 1.6;
  color: #333;
  background-color: #f5f5f5;
}

.container {
  width: 100%;
  max-width: 1200px;
  margin: 0 auto;
  padding: 0 20px;
}

header {
  background-color: var(--white);
  box-shadow: 0 2px 10px rgba(0, 0, 0, 0.1);
  position: fixed;
```

```css
  width: 100%;
  top: 0;
  z-index: 1000;
}

.nav-container {
  display: flex;
  justify-content: space-between;
  align-items: center;
  padding: 15px 0;
}

.logo {
  display: flex;
  align-items: center;
  font-size: 24px;
  font-weight: 700;
  color: var(--primary);
  text-decoration: none;
}

.logo i {
  margin-right: 10px;
  font-size: 28px;
```

```
}

nav ul {
  display: flex;
  list-style: none;
}

nav ul li {
  margin-left: 30px;
}

nav ul li a {
  color: var(--gray);
  text-decoration: none;
  font-weight: 500;
  transition: all 0.3s ease;
  position: relative;
}

nav ul li a:hover {
  color: var(--primary);
}

nav ul li a.active {
```

```
  color: var(--primary);
}

nav ul li a.active::after {
  content: '';
  position: absolute;
  bottom: -5px;
  left: 0;
  width: 100%;
  height: 2px;
  background-color: var(--primary);
}

/* Guide Section */
.guide {
  padding: 120px 0 60px;
}

.guide-header {
  text-align: center;
  margin-bottom: 50px;
}

.guide-header h1 {
```

```css
  font-size: 36px;
  color: var(--dark);
  margin-bottom: 15px;
}

.guide-header p {
  color: var(--gray);
  font-size: 18px;
  max-width: 800px;
  margin: 0 auto;
}

.guide-grid {
  display: grid;
  grid-template-columns: repeat(2, 1fr);
  gap: 30px;
  margin-bottom: 50px;
}

.guide-card {
  background-color: white;
  border-radius: 15px;
  box-shadow: 0 5px 15px rgba(0, 0, 0, 0.05);
  padding: 30px;
```

```css
  transition: all 0.3s ease;
}

.guide-card:hover {
  transform: translateY(-5px);
  box-shadow: 0 8px 25px rgba(0, 0, 0, 0.1);
}

.guide-card h2 {
  color: var(--dark);
  font-size: 24px;
  margin-bottom: 20px;
  display: flex;
  align-items: center;
}

.guide-card h2 i {
  margin-right: 10px;
  color: var(--primary);
}

.guide-card p {
  color: var(--gray);
  margin-bottom: 15px;
```

```
    }
     .guide-card ul {
      list-style: none;
      margin-left: 20px;
    }

    .guide-card ul li {
      margin-bottom: 10px;
      color: var(--gray);
      position: relative;
      padding-left: 25px;
    }

    .guide-card ul li:before {
      content: 'ç';
      position: absolute;
      left: 0;
      top: 0;
    }
  </style>
</head>
```

Chapter-8

Screenshots

8. Screenshots

This section showcases the user interface of the Plant Sense website developed for real-time monitoring and management of plant health data. The interface is designed using HTML, CSS, and JavaScript, and is connected to Firebase for data storage and retrieval. Below are the main sections of the website:

8.1 Home Page

The Home page serves as the landing interface of the website. It provides an overview of the system, a brief introduction to the project, and navigation links to other sections. It is user-friendly and visually organized to guide the user through the features of the Plant Sense platform.

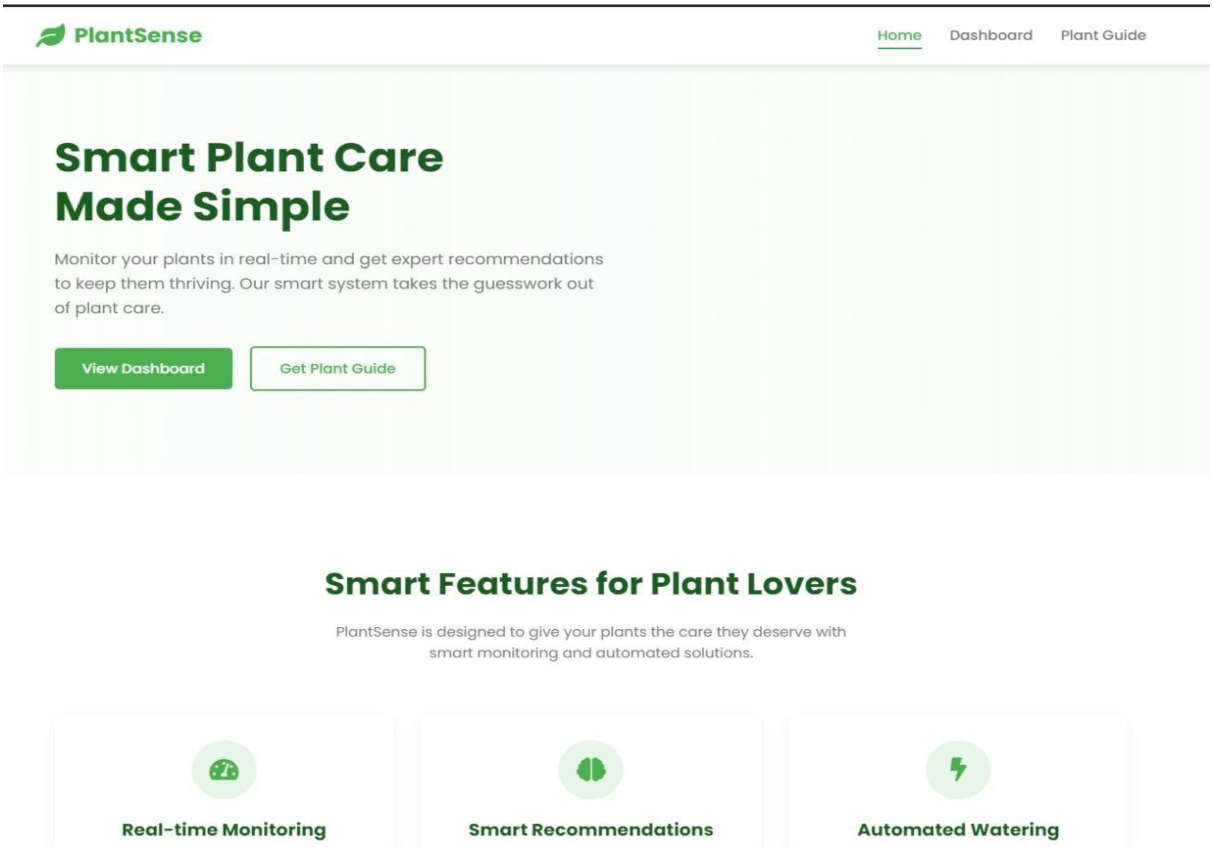

Fig.8.1: Home Page of Plant Sense

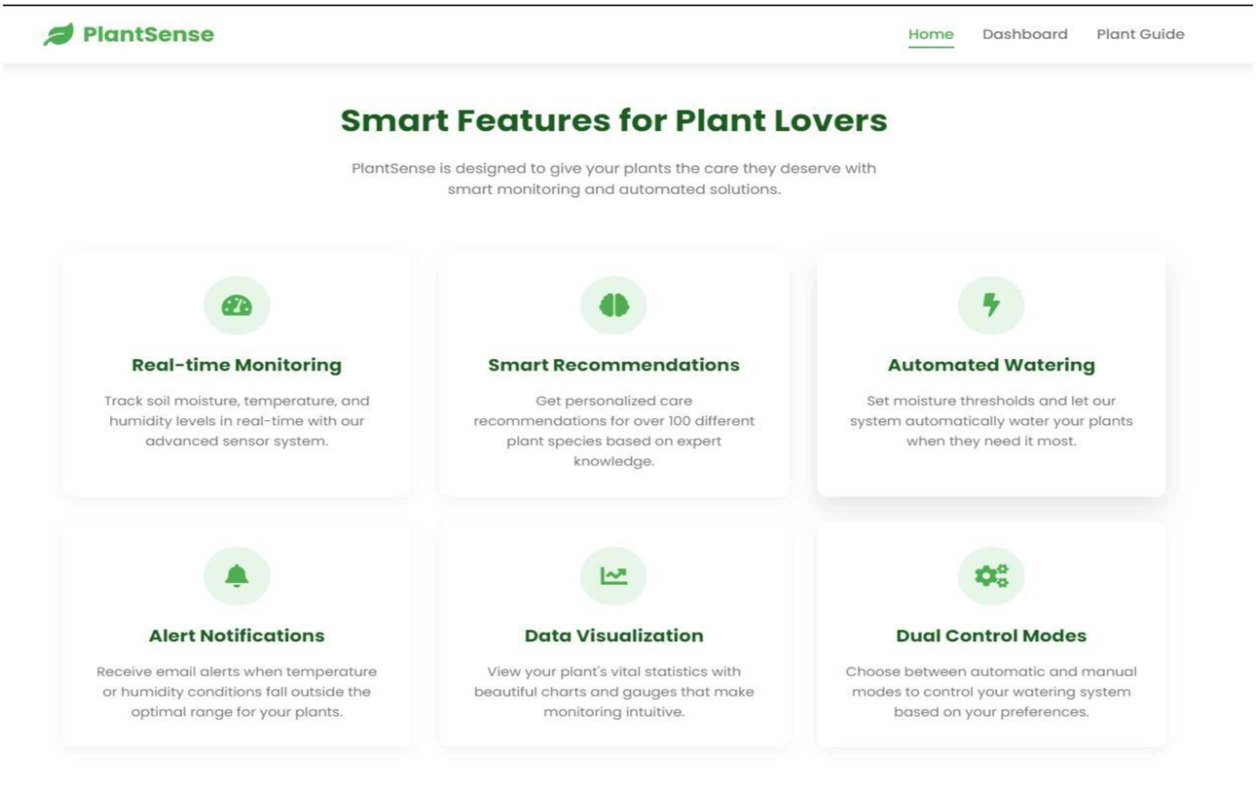

Fig. 8.2: Smart Features Offered by PlantSense

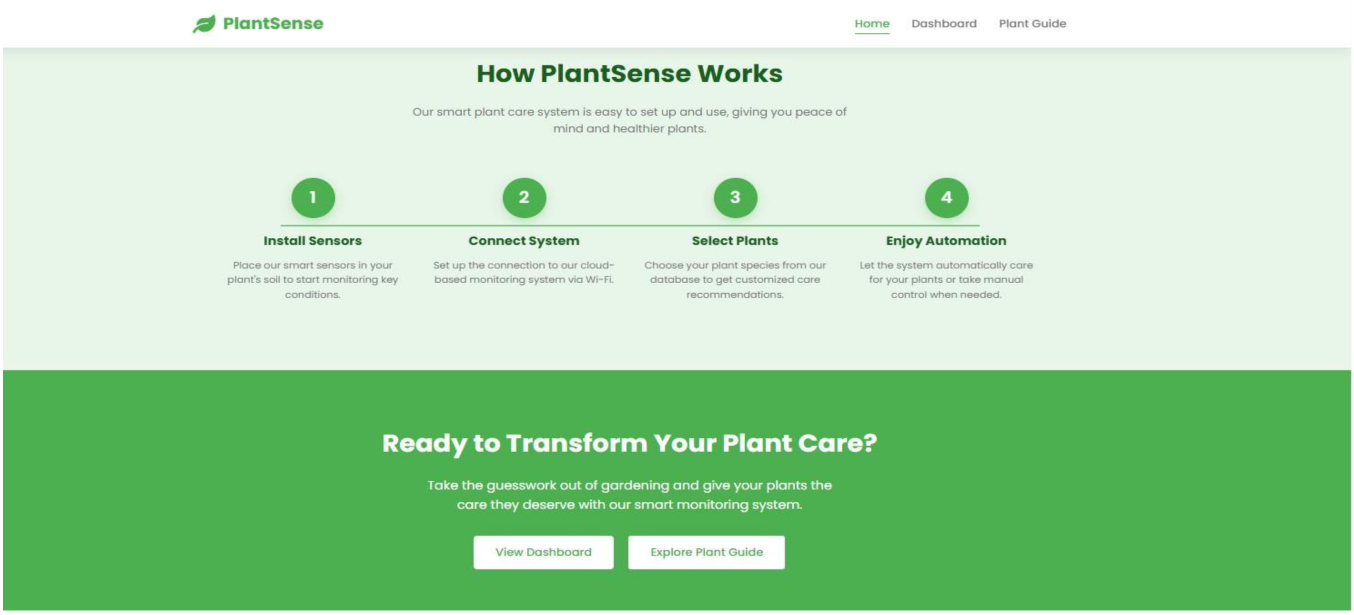

Fig.8.3: Smart Plant Care Simplified

The **Figure.8.1** and **Figure.8.2** of PlantSense homepage presents a visually appealing and intuitive interface for smart plant monitoring. The first section features a clear headline—"Smart Plant Care Made Simple"—with a brief description and call-to-action buttons for accessing the dashboard and plant guide. Below that, the site highlights six core features: real-time monitoring, smart recommendations, automated watering, alert notifications, data visualization, and dual control modes. Each feature is supported with icons and short descriptions, making the system’s capabilities easily understandable.

The **Figure.8.3** explains the process of how PlantSense works in four simple steps: installing sensors, connecting the system via Wi-Fi, selecting plant types, and enjoying automation. It visually guides the user through the setup, enhancing accessibility for all skill levels. The final section reinforces the system's benefits with a bold call to action, encouraging users to start transforming their plant care routine. The layout, consistent color palette, and minimalistic design make the homepage both functional and inviting.

8.2 Dashboard

The Dashboard is the core section where real-time sensor data is displayed. It shows temperature, humidity, and soil moisture values fetched from the IoT device via Firebase. The dashboard is dynamically updated, giving users a clear and live view of the plant conditions.

The **figure.8.4** showcases the interactive dashboard of the PlantSense system, a smart interface designed for real-time plant environment monitoring and control. The dashboard presents four main sensor readings at the top: current temperature (31.7°C), humidity (49.4%), soil moisture (0%), and pump status (OFF). These metrics provide a clear snapshot of environmental conditions relevant to plant maintenance. Each data point is accompanied by an icon for visual clarity and quick recognition.

Below the sensor data, a line graph labeled “Sensor History” tracks and displays temperature, humidity, and soil moisture trends over time. This allows users to observe changes and make informed decisions. To the right, a circular gauge displays the current soil moisture level in an intuitive analog format.

The bottom section of the dashboard features three adjustable threshold panels: Moisture Threshold, Temperature Threshold, and Humidity Threshold. Users can set minimum and maximum values for each, ensuring the system performs automatic actions—such as turning on the water pump—when conditions deviate from ideal ranges. Sliders and input fields make customization easy. The dashboard design is clean, modern, and accessible, helping users maintain optimal conditions for plant care through automation and intelligent monitoring. This streamlined interface empowers users to effortlessly manage plant health, combining technology and simplicity for an efficient monitoring experience.

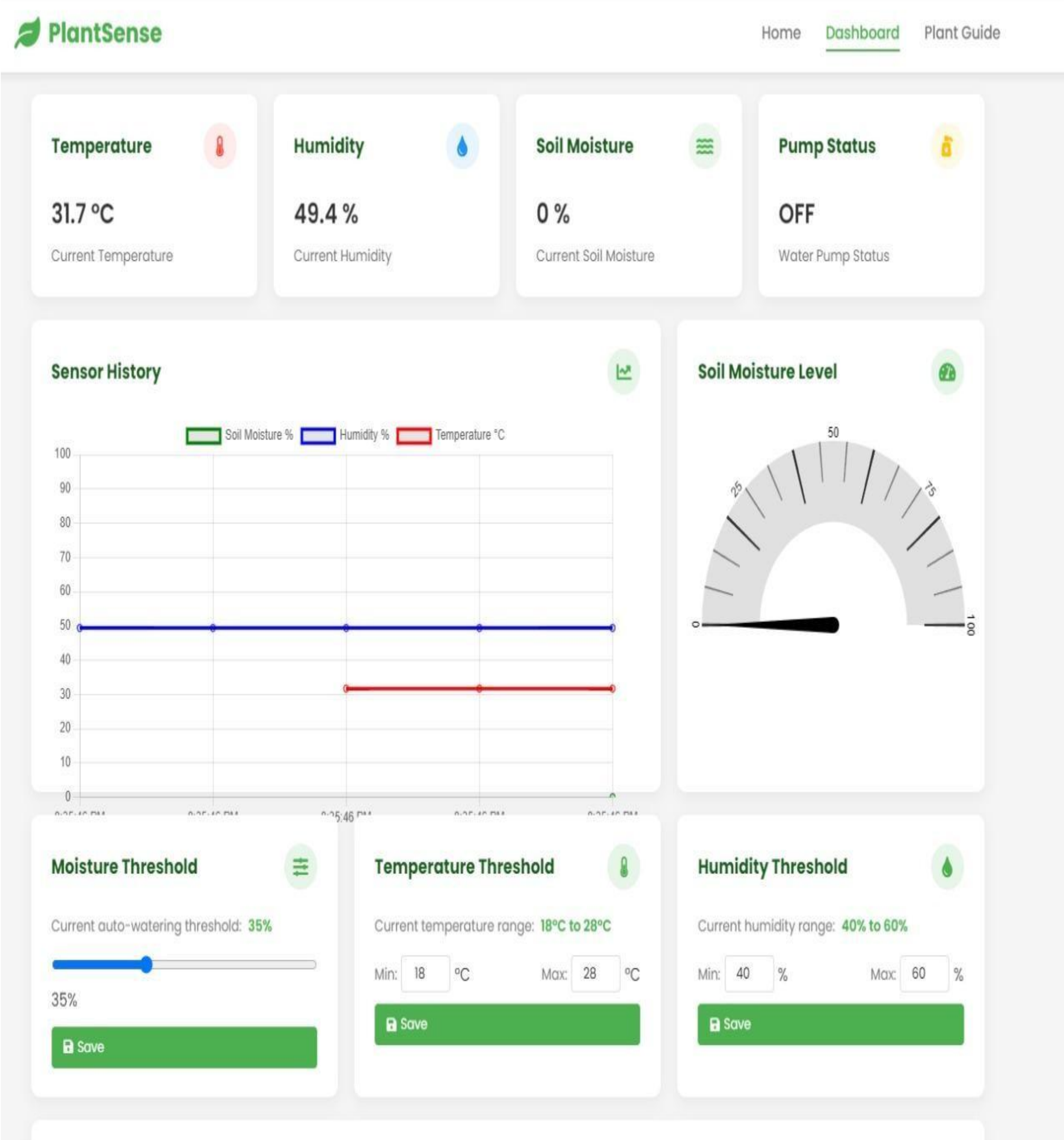

Fig.8.4: PlantSense Dashboard with Environmental Monitoring

The below **figure.8.5** shows the plant selection and notification settings interface of the PlantSense system. On the left side, users can search and select a specific plant—here, "Aloe Vera" is chosen from the dropdown list. This enables the system to tailor recommendations and thresholds specific to that plant's care requirements. On the right side, the notification panel allows users to input an email address to receive alerts. The user has enabled both "Critical water level alerts” and “Pump status notifications,” ensuring timely updates. A green button labeled “Save Settings” confirms changes, and a status message below indicates that notifications are currently active. This interface helps users stay informed and in control of their plant’s environment remotely and efficiently.

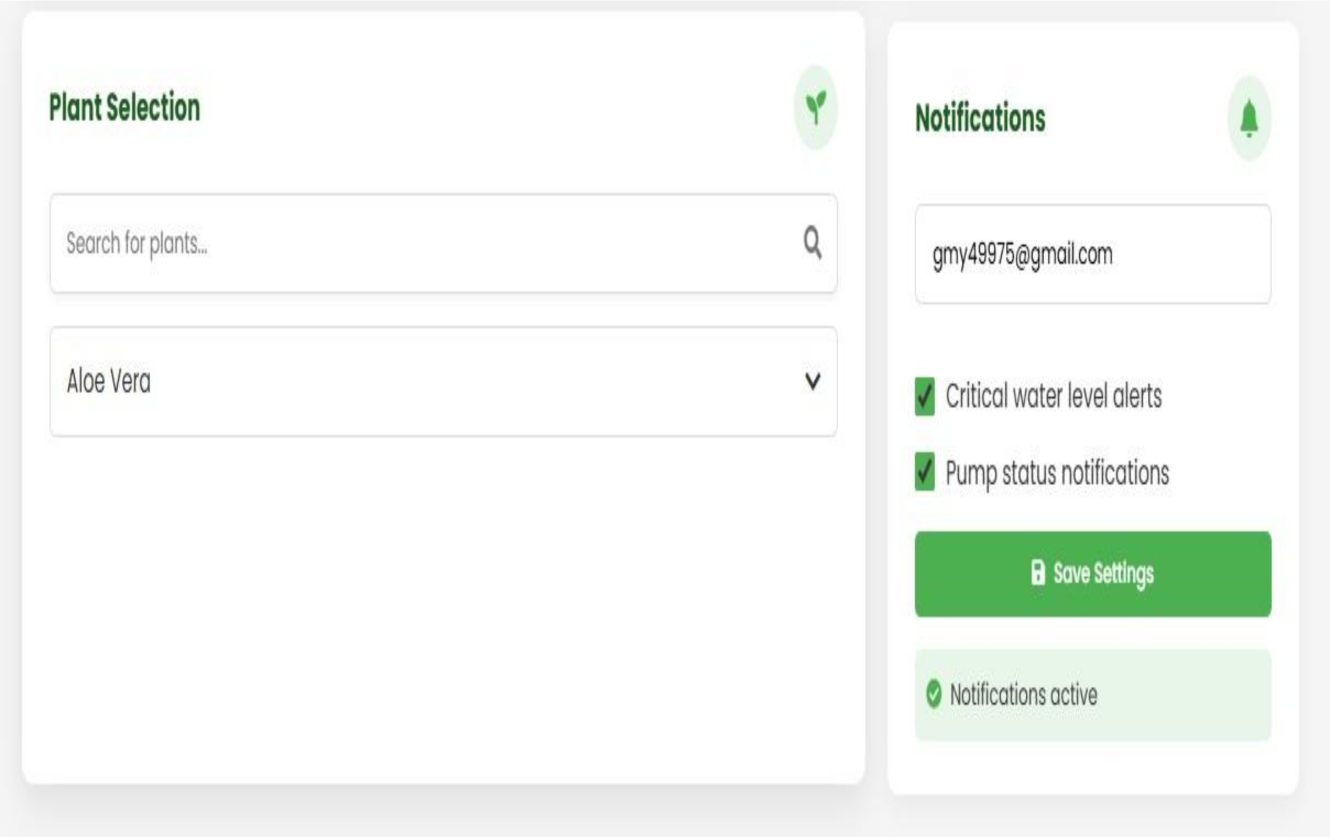

Fig.8.5: Plant Selection and Alert Settings

8.3 Plant Guide

The **figure.8.6** displays the "Plant Care Guide" section of the PlantSense system, offering essential tips to help users maintain healthy indoor plants. The guide is neatly divided into four informative categories.

The “Light Requirements” section helps users understand how different light levels affect plant growth. It ranges from direct sunlight (6+ hours daily) to low light (suitable for darker indoor areas), helping users choose the best placement for their plants.

The “Watering Guide” outlines proper hydration practices—checking soil moisture before watering, watering until it drains from the bottom, allowing soil to dry between waterings, and adjusting based on seasonal changes.

The "Temperature & Humidity" panel provides ideal indoor conditions: temperatures between 18–24°C and humidity levels from 40–60%. It also recommends avoiding drafts and using humidifiers in dry conditions to promote plant health.

Finally, the "Soil & Fertilization" section emphasizes the importance of well-draining potting mix, timely fertilization, repotting as needed, and refreshing soil every 1–2 years.

Overall, the guide serves as a comprehensive, beginner-friendly reference for indoor plant care.

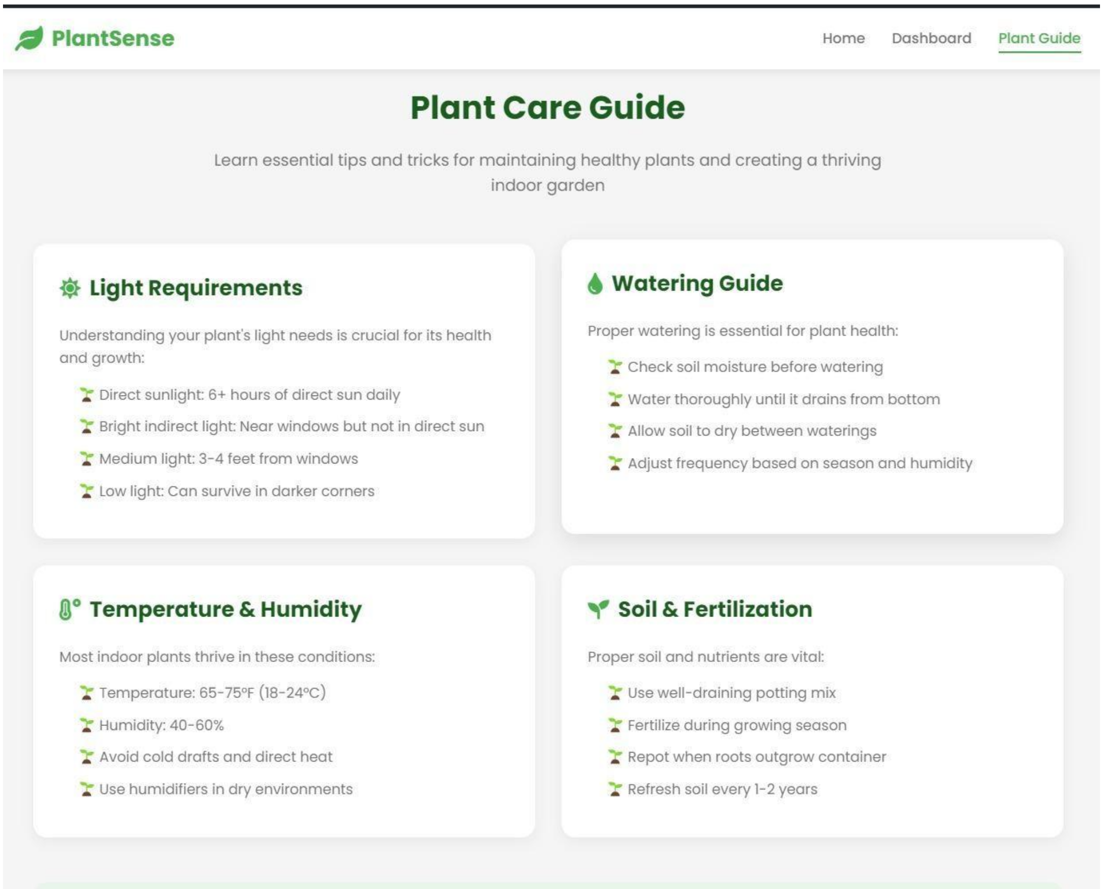

Fig.8.6: Essential Tips for Plant Care

The **figure.8.7** presents a section of the PlantSense guide focused on essential plant care tips and the benefits of indoor plants. The top portion outlines six key practices: regular inspection for pests and stress, pruning dead leaves, rotating plants for balanced light exposure, cleaning leaves to support photosynthesis, adjusting care seasonally, and recognizing early signs of plant distress. The lower portion lists the advantages of having indoor plants, including air purification, stress reduction, mood enhancement, aesthetic improvement in homes, and health benefits like better sleep and lower blood pressure. Together, these tips and benefits promote healthier, happier plants and more pleasant indoor environments.

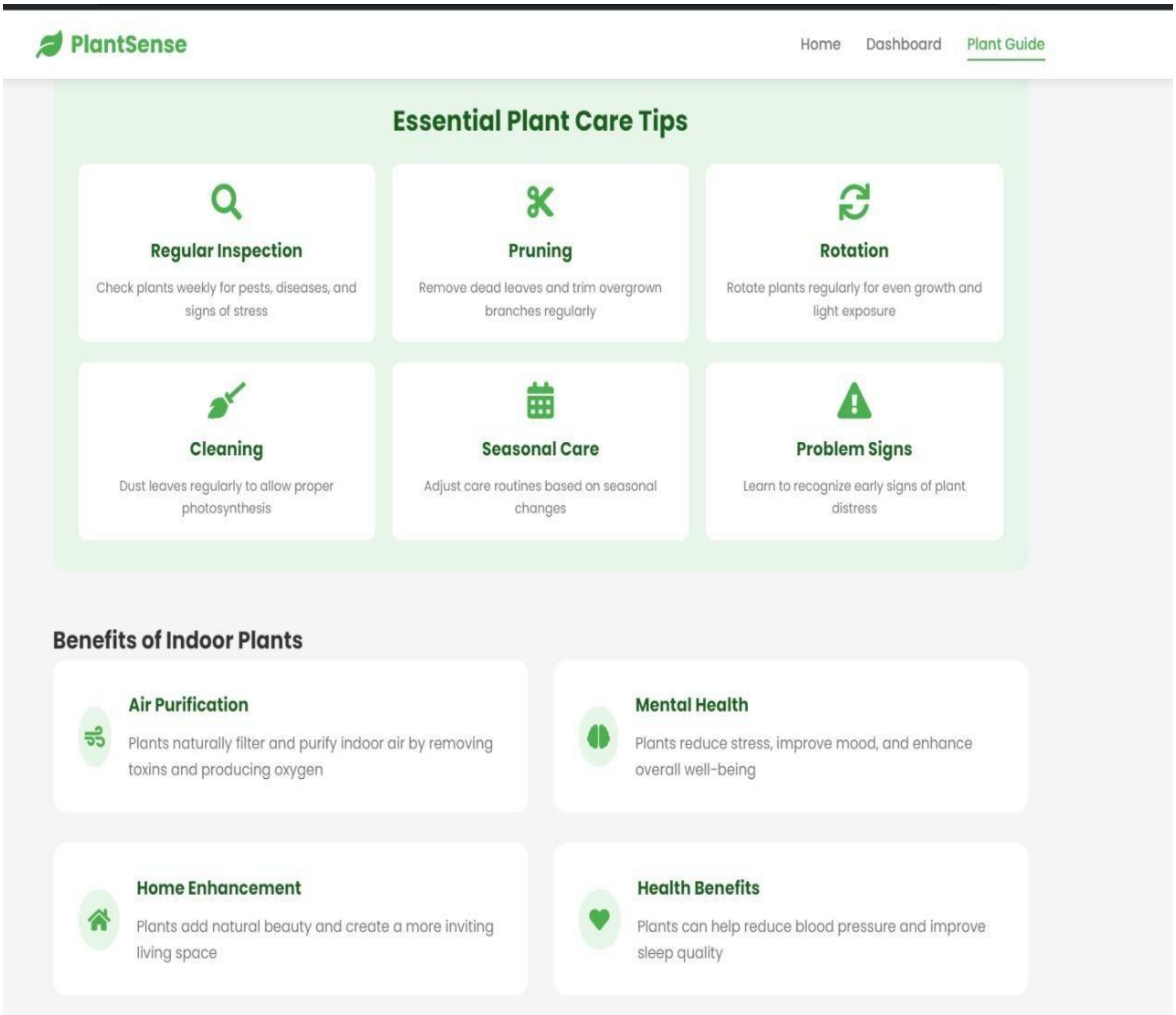

Fig.8.7: Quick Guide to Thriving Plants

8.4 Real-Time Gmail Notification

When the system detects abnormal conditions—such as low soil moisture or extreme temperatures—it sends an automated email alert to the registered user. This ensures the user can take immediate action even when not actively checking the dashboard.

8.4.1 Real-Time Gmail Notification for water level

Figure.8.8 shows an email alert generated by the PlantSense system, informing the user that the soil moisture level for their Aloe Vera plant has reached a critical 0%, which is below the defined threshold of 17%. Since the system is in Manual Mode, the user is advised to activate the water pump manually. The alert includes the exact timestamp for reference.

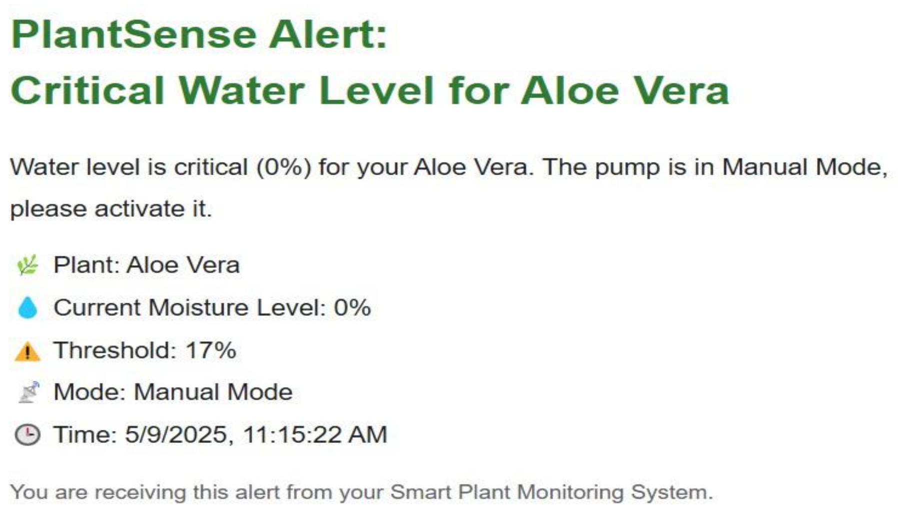

Fig.8.8: Gmail Notification for Water Level

8.4.2 Real-Time Gmail Notification for Temperature Range

Figure.8.9 displays a real-time Gmail notification from the PlantSense system indicating that the temperature for the Aloe Vera plant has exceeded the optimal range. The recorded temperature is 30.7°C, while the ideal range is 20°C to 30°C. This alert helps users respond promptly to unfavorable environmental conditions and maintain a stable temperature for healthy plant maintenance.

Fig.8.9: Gmail Notification Screenshot for Temperature

8.4.3 Real-Time Gmail Notification for Humidity Range

Fig.8.10 illustrates a real-time Gmail alert from the PlantSense system, notifying the user that humidity for the Aloe Vera plant has reached 52%, which exceeds the optimal range of 40% to

50%. This prompt enables users to take corrective measures and maintain suitable humidity conditions for plant well-being.

Fig.8.10: Gmail Notification Screenshot for Humidity

8.5 Firebase Realtime Database Structure

Figure.8.11 shows a section of the Firebase Realtime Database structure used in the Plant Monitoring System. It includes key parameters such as device status, humidity value, operation mode, pump status, and user email. These attributes help manage real-time sensor data, control logic, and notification delivery effectively.

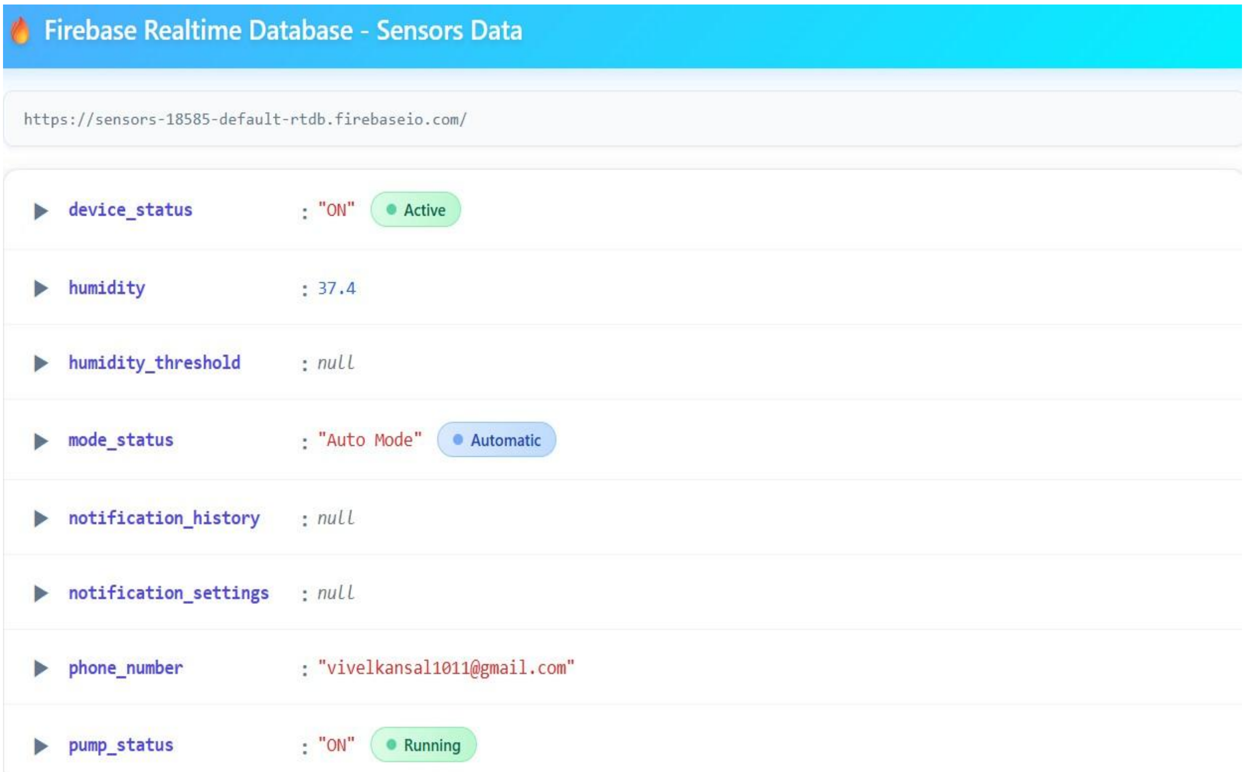

Fig.8.11: Firebase Realtime Database Structure

Chapter-9

Conclusion and Future Scope

9.1 Conclusion

The development of the IoT Based Plant Monitoring System marks a significant advancement in the way we monitor and care for plants through automation and technology. The system offers an efficient, real-time, and remote solution for plant health monitoring by integrating multiple hardware and software components in a cohesive structure. Through the use of sensors such as the Soil Moisture Sensor and DHT11 (for temperature and humidity), along with NodeMCU (ESP8266) for connectivity, and a relay-operated water pump, the system provides accurate, automated responses to the changing environmental conditions surrounding a plant.

One of the key contributions of this system is its ability to reduce human intervention without compromising the care quality plants receive. The project successfully demonstrates how IoT technology can be leveraged to collect environmental data, analyze it, and trigger appropriate actions in real-time. This ensures that plants are neither under- nor over-watered, and it helps maintain optimal temperature and humidity conditions conducive to plant growth.

Another remarkable aspect of this system is its integration with Firebase, which allows seamless real-time data transfer and storage. This data is displayed on a user-friendly web interface developed using HTML, CSS, and JavaScript, making it accessible across devices and easy to understand. The website, named Plant Sense, includes structured sections such as Home, Dashboard, and Plant Guide, providing users with both live updates and educational resources to enhance their plant care knowledge.

A standout feature is the system's email notification functionality, which immediately alerts users whenever sensor readings indicate that attention is needed. This feature is particularly useful in remote monitoring scenarios or for users who cannot frequently check the system dashboard. The prompt alert mechanism adds a layer of reliability and responsiveness, making the system highly practical for everyday use.

Throughout the project, various challenges were encountered, including sensor calibration, consistent connectivity, and ensuring real-time responsiveness between hardware and cloud services. These challenges were addressed through iterative testing, optimizing code, and refining the circuit design. The outcome is a robust and functional prototype that not only achieves the set objectives but also opens new opportunities for technological application in routine plant care and maintenance.

The comparative analysis with other similar projects highlights the innovation and practicality of our system. While many existing systems focus only on individual components like moisture sensors or timers, our project integrates real-time monitoring, cloud connectivity, automation, and user interactivity in a cost-effective way. The use of NodeMCU instead of more expensive platforms like Raspberry Pi also makes it highly accessible for students, hobbyists, and households.

In conclusion, the IoT Based Plant Monitoring System is a step forward toward smart, sustainable, and automated plant care. It simplifies the process of monitoring plant health, conserves water through targeted irrigation, and enhances user engagement through interactive web visualization and notifications. The system addresses common challenges faced by individuals who wish to maintain plant health but are limited by time, knowledge, or physical presence. It proves to be not just a project but a scalable solution with potential for future upgrades such as mobile app integration, AI-based plant health prediction, or solar-powered operation. With further refinement, this project can serve as a foundation for real-world smart plant monitoring solutions.

9.2 Future Scope

1. **Integration of Machine Learning Algorithms**
   - Predictive analytics can be used to forecast irrigation needs based on historical data, weather patterns, and plant behavior.
   - Helps in detecting unusual patterns which may indicate diseases or environmental stress.
2. **Expansion of Sensor Network**
   - Additional sensors such as pH level, light intensity, CO_2, and nutrient level sensors can be integrated.
   - This would enable a more comprehensive plant health analysis and tailored care.
3. **Solar Power Integration**

- Implementing solar panels can make the system energy-efficient and suitable for remote or off-grid environments.
- Reduces dependency on electricity and enhances environmental sustainability.

4. **Mobile Application Development**
    - Though currently web-based, a dedicated cross-platform mobile app can be developed for more interactive control.
    - Push notifications for real-time alerts, system faults, or threshold breaches can be added.
5. **Offline Data Storage and Sync**
    - Incorporating local storage options when internet connectivity is unavailable.
    - Automatic synchronization to the cloud when connectivity resumes, ensuring no data loss.
6. **Voice Assistant Integration**
    - Future versions can integrate voice control through platforms like Google Assistant or Amazon Alexa.
    - Enables users to interact hands-free and monitor status using voice commands.
7. **Custom Cloud Infrastructure**
    - Shifting from Firebase to a custom cloud platform can provide better data privacy, analytics control, and advanced dashboard features.
    - Allows hosting on private servers or local networks if required.
8. **Scalability for Multiple Plants**
    - The system can be extended to monitor and manage multiple plants or sections by using a mesh network of microcontrollers.
    - Suitable for greenhouses, gardens, or large indoor setups.
9. **User Authentication and Access Control**
    - Adding login systems and user roles to allow multiple users with different access levels.

- Useful for shared spaces like institutional labs or office environments.

10. **Automatic Nutrient Dispensing System**
    - Integration of actuators to control nutrient dispensers based on plant needs.
    - Promotes balanced growth and reduces manual fertilization efforts.
11. **Data Analytics and Visualization**
    - Advanced charts, graphs, and trend visualizations can help users understand long-term plant behavior.
    - Useful for research and optimization.
12. **Commercial Product Development**
    - The prototype can be transformed into a full-fledged marketable product.7
    - Can cater to hobbyists, urban gardeners, or educational institutions.
13. **Integration with Weather APIs**
    - The system can connect to real-time weather forecasting APIs to adjust irrigation schedules accordingly.
    - Helps prevent unnecessary watering during rain or unfavorable weather conditions.
14. **Automated Reporting and Logging**
    - Daily, weekly, or monthly reports can be generated to track plant health and system performance.
    - Beneficial for long-term monitoring, analysis, and record keeping.
15. **Multi-Language and Accessibility Support**
    - Future versions can include multilingual interfaces and accessibility options for users with disabilities.
    - Enhances usability and broadens the system's reach to diverse user groups.

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IOT-Based Plant Monitoring System Using NodeMCU

[1]Vivek Kansal, [2] Utkarsh Rai, [3]Vivek Kumar, [4]Mrs. Archana Singh
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Abstract: **It can be difficult to care for plants, particularly for those with hectic schedules or little experience with plant requirements. Poor plant health or even death might result from forgetting to water plants or from not knowing if they are in the proper setting. The goal of this research is to use the Node MCU (ESP8266) microcontroller to create an Internet of Things-based plant monitoring system in order to address this issue [10]. The system assists users with real-time monitoring of important environmental parameters like as temperature, humidity, and soil moisture. The system gathers information from the plant's environment using sensors that are connected to the Node MCU and transmits it via Wi-Fi to a mobile application. After that, the user can monitor these data whenever they want and get notifications if the plant need maintenance. For example, if the soil moisture is too low, a notification is sent, reminding the user to water the plant. In advanced versions, a small water pump can be added to automatically water the plant without human intervention. This smart system is designed to be low-cost, simple, and effective for home use, urban gardening [9]. It promotes healthy plant growth by ensuring that plants receive the right care at the right time.**

Keywords: IoT, Node MCU, Plant Monitoring, Soil Moisture Sensor, Real-Time Data, Automated Irrigation

1. INTRODUCTION

In the last few years, the Internet of Things (IoT) has become a game-changing technology in the conversion of traditional systems to smart, automated and energy-efficient solutions [10]. Soil moisture, temperature, humidity, etc., are some of the factors that are sometimes hard for farmers or plant lovers to keep a check on the environmental conditions of plants. Monitoring these factors manually can be tedious and inexact, especially for people managing several plants or large spaces [8].

This project focuses on creating a smart plant monitoring system using NodeMCU, a low-cost microcontroller with built-in Wi-Fi capabilities. The aim is to design a system that can monitor essential environmental parameters and provide real-time updates to the user through an IoT platform. By integrating sensors with NodeMCU, we can track data like soil moisture, air temperature, and humidity, and send this information to a cloud service or mobile app for easy access.

This project aims to provide accurate, timely data to help users take better care of their plants [1]. Whether it's a home garden, a greenhouse or a small farm, this system can help ensure that plants receive optimal conditions to grow. It cuts down on the need for constant manual checking and lets users respond immediately if something goes wrong. This paper presents the design, implementation, and testing of the IoT-based plant monitoring system, highlighting its usefulness, simplicity, and potential for future expansion.

2. Literature Review

IoT has transformed by enabling real-time monitoring of environmental factors like soil moisture, temperature, and humidity [2]. Systems such as Xiaomi’s Mi Flora offer smart monitoring, but open-source setups using NodeMCU provide more flexibility [13]. A 2022 study in Sensor’s journal detailed a low-cost, IoT-based plant monitoring system using ESP8266 and DHT11 sensors, ideal for small-scale farms and home gardens [1]. NodeMCU is popular for its built-in Wi-Fi and compatibility with cloud platforms like ThingSpeak. These systems help optimize water usage, reduce manual labor, and provide timely alerts to improve overall plant health and growth [3].

2.1 Overview of IoT in Plant Monitoring Systems

The Internet of Things (IoT) has become an essential part of smart living—connecting devices, sensors, and everyday objects to the internet so they can collect, share, and respond to data in real-time [19]. One of its growing applications is in indoor and decorative plant monitoring, especially in homes, offices, and public spaces. Many people today keep indoor plants not just for aesthetics but also to improve air quality and create calming environments. However, caring for them regularly can be challenging—especially in busy lifestyles [7]. This is where IoT-based plant monitoring systems come in.

These systems typically use sensors to measure soil moisture, temperature, light intensity, and humidity around the plant [5]. The data is then sent to a smartphone or web dashboard, helping users understand when to water, move, or adjust lighting for their plants—without guesswork. In 2024, many smart homes began integrating these systems with assistants like Alexa or Google Home, so users could ask about their plant's condition or receive automated reminders [8]. These solutions are not just for plant enthusiasts—they're also popular in tech-enabled cafes, hotel lobbies, co-working spaces, and libraries where plants are displayed, but regular maintenance is hard to manage manually. IoT plant monitoring makes greenery smarter, easier, and perfectly suited for modern indoor spaces.

2.2 Existing Plant Monitoring Systems

Plants monitoring systems are getting popular in home, offices and public indoor surfaces [17]. When it comes to air-purifying indoor plants or decorative greenery, people are definitely more aware of their surroundings now." These systems enable users to monitor the health of their plants without constantly checking in on them.

For example, the **Xiaomi Mi Flora Sensor** is a smart Bluetooth-enabled device that tracks soil moisture, temperature, light levels, and fertilizer quality [1]. It pairs with a smartphone app and gives users real-time notifications. If the light is too low or the soil is dry, it sends an alert. This is particularly useful in places like corporate offices or apartments where people might not have the time or experience to maintain plants properly [17].

There are also several open-source systems made using NodeMCU components, DHT11 temperature and humidity sensors, and soil moisture probes [18]. These are often created by tech enthusiasts looking to build their own smart home plant care systems. For example, someone living in a smart apartment might integrate a custom plant monitor with their smart home assistant like Alexa or Google Home, receiving voice alerts or even automating a water pump. In 2023, hobbyists shared projects online where small succulents or bonsai trees were monitored using IoT systems that sent notifications via Telegram or push alerts to their phones [18]. These examples show that modern plant monitoring isn't just about farming—it's also about making everyday living spaces more sustainable, green, and tech-savvy.

2.3 Role of NodeMCU in IoT Projects

NodeMCU is a popular choice for IoT projects due to its affordability, built-in Wi-Fi, and Arduino compatibility [12]. It is widely used in smart home applications. For instance, in 2024, a group of students in India developed a smart greenhouse system using NodeMCU and DHT22 sensors to maintain humidity levels automatically. This highlights how NodeMCU empowers DIY developers to build effective, real-time systems with limited budgets and technical complexity [13].

3. System Design and Architecture

An IoT-based plant monitoring system is designed to help users care for plants more efficiently by using smart sensors and devices that monitor environmental conditions and automate responses [9]. This is especially useful in homes, offices, schools, cafés, and any space where plants are part of the environment.

3.1 Hardware Components

The system is built using a **NodeMCU (ESP8266)**, a compact microcontroller with built-in Wi-Fi that acts as the brain of the system [4]. Connected to it are sensors that measure key parameters:

3.1.1 NodeMCU (ESP8266)

NodeMCU is a microcontroller with built-in Wi-Fi, making it ideal for IoT projects. It reads data from sensors and sends it to the cloud for real-time monitoring. Its compact size, low cost, and compatibility with Arduino IDE make it popular for beginners and hobbyists building smart systems like automated plant monitoring [12].

Fig-3.1.1: NodeMCU (ESP8266)

3.1.2 Soil Moisture Sensor

This sensor detects how much water is in the soil. It uses two probes that measure resistance between them: more water means lower resistance [13]. The sensor helps determine when the plant needs watering. It sends analog signals to the NodeMCU, allowing for timely notifications or automated irrigation if connected to a pump [13].

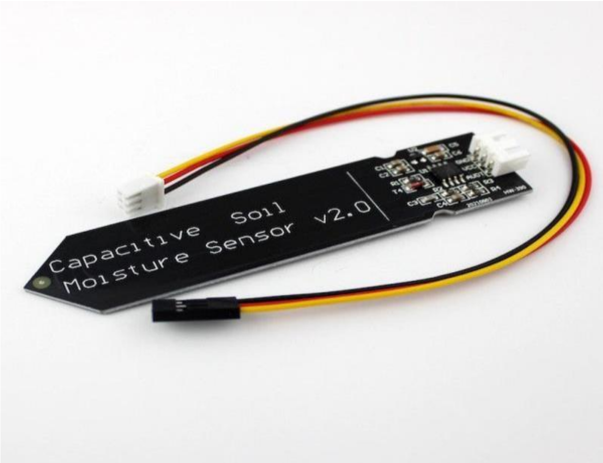


Fig-3.1.2: Soil Moisture Sensor

3.1.3 DHT11 (Temperature and Humidity Sensor)

The DHT11 sensor measures the surrounding air temperature and humidity. It uses a thermistor for temperature and a capacitive sensor for humidity. This data helps users monitor the indoor environment around the plant, ensuring it's within suitable ranges for plant health, especially in indoor settings like homes or offices [5].

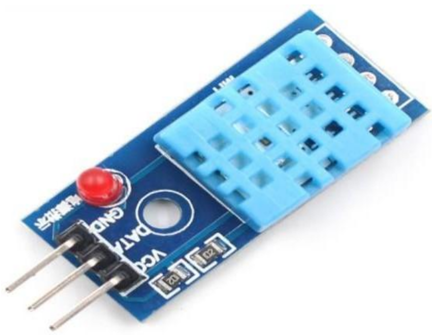


Fig-3.1.3: DHT11 (Temperature and Humidity Sensor)

3.1.4 Relay Module

A relay module acts like a switch controlled by the NodeMCU. It's used to turn on or off high-power devices, like a small water pump. When the soil is dry, the NodeMCU sends a signal to the relay, which activates the pump to water the plant automatically—perfect for hands-free care [5].

Fig-3.1.4: Relay Module

3.1.5 Water Pump

A water pump is an electric device that moves water from one place to another. In IoT plant monitoring systems, a small DC water pump is used to automatically water plants when soil moisture is low [1]. Controlled by a relay and powered by an external source, it ensures plants stay hydrated without manual effort.

Fig-3.1.5: Water Pump

3.2 Sensor Integration and Data Flow

The heart of this smart plant monitoring system lies in how sensors work together and communicate data. Each sensor plays a specific role—measuring factors like soil moisture, temperature, humidity, and light intensity. These sensors are physically connected to a NodeMCU microcontroller, which acts as the brain of the system. Once powered on, each sensor collects real-time data from the environment around the plant [7]. For example, the soil moisture sensor constantly checks how dry the soil is, while the DHT11 sensor monitors air temperature and humidity. All this information is passed to the NodeMCU, which processes the data and sends it over Wi-Fi to platform. These platforms display the data in graphs or dashboards, allowing users to monitor plant conditions anytime via smartphone or web browser [8]. In more advanced setups, the system can also trigger actions—such as sending notifications or turning on a small water pump if the soil is too dry. This setup makes it incredibly convenient for busy people who want to care for plants without constant checking or guesswork [11].

3.3 Circuit Diagram and Connections

In this smart plant monitoring system, each component connects with the NodeMCU (ESP8266) to form a simple yet effective circuit. The soil moisture sensor is inserted into the plant's soil. It detects how wet or dry the soil is and sends an analog signal to the NodeMCU's A0 pin. This data helps determine if the plant needs water. The DHT11 sensor tracks surrounding temperature and humidity.

It connects to a digital pin (like D4) and shares environmental readings with the NodeMCU through a single data wire, using minimal power and wiring. When the soil becomes too dry, the NodeMCU sends a signal to the relay module—an electronic switch connected to a digital pin (e.g., D1) [1,3].

The relay acts as a bridge between the low-power NodeMCU and a higher-power device like a pump. The relay then activates the small water pump, which is powered by an external 5V–9V power source. This pump draws water from a container and delivers it to the plant automatically. All components share a common ground and are powered through the NodeMCU or an external power supply. The circuit is simple enough for a small breadboard setup and can be expanded as needed [11].

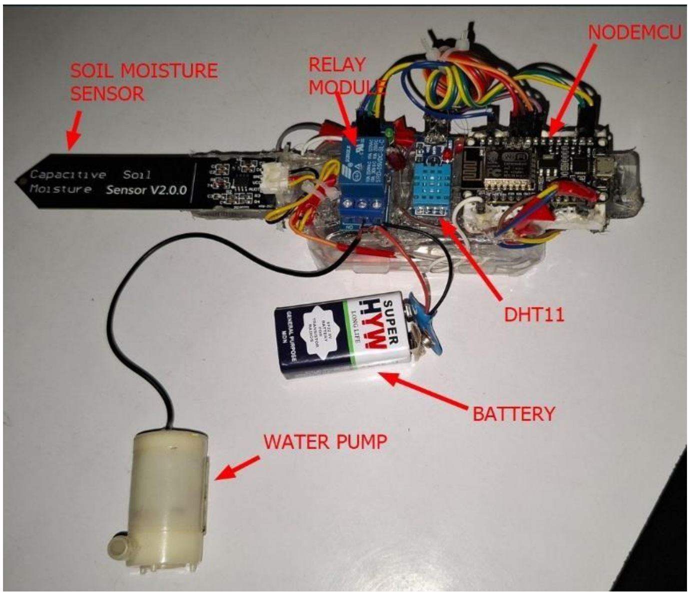


Fig-3.3: Circuit Diagram

4. Detailed Research on Commonly Grown Indoor and Outdoor Plants in India

4.1. Aloe Vera

Aloe vera is a succulent plant valued for its medicinal, cosmetic, and ornamental uses. It is extremely hardy and popular in Indian households for its easy maintenance and healing properties.

Parameter	Requirement
Temperature	Ideal range: 20-30°C (68-86°F) Maximum tolerance: 40°C (104°F) Minimum tolerance: 5°C (41°F) - frost sensitive
Moisture	Water every 14-21 days in summer Water every 30 days in winter Very low water requirement overall
Humidity	Optimal range: 30-50% Excessive humidity may cause fungal problems
Soil	Well-draining sandy soil or cactus potting mix pH: 6.0-7.0

4.2. Rose

Roses are classic ornamental plants highly popular for their beautiful blooms and fragrance. In India, roses are grown both in gardens and as potted plants on terraces and balconies.

Parameter	Details
Temperature	Ideal range: 15-28°C, Flowering best at 16-24°C, Can tolerate up to 35°C with regular watering
Moisture	Requires moderate moisture, Water deeply 2-3 times a week (depends on weather)
Humidity	Prefers moderate humidity (50-70%), High humidity can lead to fungal diseases like black spot or powdery mildew
Soil	Fertile, well-drained loamy soil enriched with compost

4.3. Money Plant

Money Plant is one of the most loved indoor plants in India, associated with good luck and wealth. It’s known for being very forgiving and thriving even in neglect.

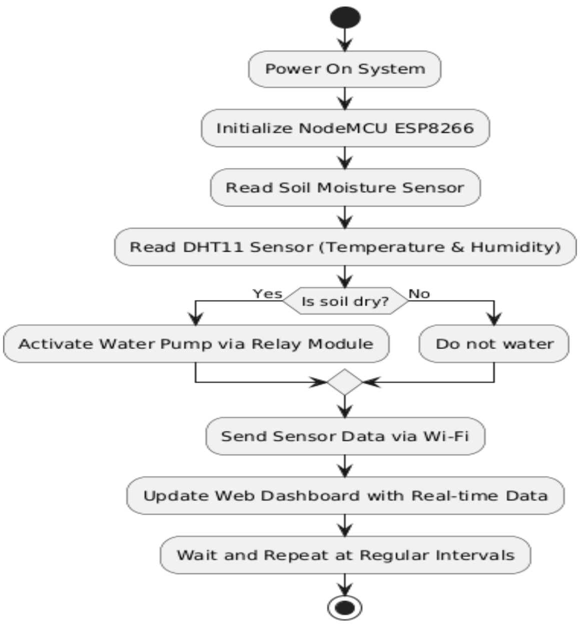
Parameter	Details
Temperature	Ideal range: 18-30°C, Cannot tolerate temperatures below 10°C
Moisture	Moderate water needs, Water once top 1-2 inches of soil feel dry
Humidity	Prefers moderate to high humidity (50-80%), Benefits from occasional misting in dry indoor air
Soil	Light, well-draining potting mix, Can even grow in water jars for months

5. Methodology

This research involved the design, development, and testing of an IoT-based system for monitoring key environmental parameters essential to plant health—specifically, temperature, humidity, and soil moisture [1]. The system was implemented using real hardware components and tested on three different plants: Aloe Vera, Rose Plant, and Money Plant.

5.1 System Architecture

The system uses a NodeMCU ESP8266 microcontroller as the central processing and communication unit. It is connected to three primary sensors: a soil moisture sensor to sense the water level in the soil, and a DHT11 sensor to sense ambient temperature and humidity. NodeMCU operates a water pump via a relay module to automate watering. All sensor readings are transmitted to a web-based dashboard through Wi-Fi, where real-time values can be tracked and control actions can be initiated remotely [4,5].



5.2 Plant Selection

The study focused on:

- **Aloe Vera** – a drought-tolerant plant requiring minimal watering.
- **Rose Plant** – needing moderate watering and temperature control.
- **Money Plant** – thriving in balanced moisture and humidity.

Each plant was placed in a controlled environment. Threshold values were set based on their specific requirements, and data was collected over several days [1].

5.3 Data Collection and Monitoring

Sensor readings were collected every 10 seconds. The soil moisture, temperature, and humidity values were recorded and displayed on the web dashboard [11]. Predefined moisture thresholds were used to trigger irrigation automatically. Each plant's behavior was observed based on the sensor readings, and changes in health were noted to assess the system's effectiveness in maintaining optimal conditions [12,6].

6. Results and Discussion

The IoT-based plant monitoring system was tested on three plants — Aloe Vera, Rose Plant, and Money Plant — to observe how the system could monitor and maintain optimal environmental conditions like soil moisture, temperature, and humidity [19]. Over a 10-day period, the system efficiently automated the monitoring and watering processes, ensuring that each plant received appropriate care according to its specific needs [20].

6.1 System Testing and Output

The system was tested to measure the soil moisture, temperature, and humidity levels of the three plants. Aloe Vera, Rose Plant, and Money Plant each had their own thresholds for watering based on their individual climate requirements. For instance, the Aloe Vera plant triggered the pump when soil moisture fell below 17%, while the Rose Plant required higher moisture levels (around 35%) before irrigation was initiated and for money plant below 30%. The data collected through the system was displayed in real-time on the web dashboard. For Aloe Vera, soil moisture ranged from 12% to 27%, while Rose Plant's moisture ranged from 42% to 58%. The Money Plant's moisture fluctuated between 32% and 49%. Additionally, the system recorded the temperature and humidity for each plant: Aloe Vera was best suited in the range of 19°C–26°C with humidity levels between 35%–48%, whereas the Rose Plant required slightly higher humidity (45%–65%) and the Money Plant preferred humidity levels of 55%–70%. The system displayed accurate and real-time data for all these parameters, ensuring precise monitoring.

Parameter	Aloe Vera	Rose Plant	Money Plant
Display Method	Web Dashboard (Real-time)		
Soil Moisture Range	12% - 27%	42% - 58%	32% - 49%
Watering Threshold	Below 17%	Below 35%	Below 30%
Temperature Range	19°C - 26°C	18°C - 25°C	18°C - 30°C
Humidity Range	35% - 48%	45% - 65%	55% - 70%

6.2 Performance Evaluation

The system performed excellently throughout the testing period, ensuring that all three plants remained healthy and within their preferred environmental conditions [12]. For Aloe Vera, the system effectively maintained lower soil moisture levels as per its needs, allowing the plant to thrive. The Rose Plant required frequent watering, and the system responded quickly by triggering the water pump when soil moisture levels dropped to about 40%. The system also maintained ideal temperature and humidity for all three plants, with minor fluctuations not affecting their overall health. The system's performance was evaluated based on the accuracy of readings from the sensors and how well it adapted to varying environmental conditions [16,6]. Soil moisture, temperature, and humidity readings were stable, and the water pump was activated accurately each time the moisture levels fell below the threshold. The system also showed a high level of reliability, as there were no sensor malfunctions or delays in water delivery. In terms of time efficiency, the system was able to react promptly to changes in the plant environment, ensuring plants received care exactly when needed [14].

6.3 Advantages and Limitations

One of the major advantages of the IoT-based plant monitoring system is its ability to automate plant care. For Aloe Vera, which requires minimal watering, the system prevented overwatering, which is a common problem for many plant owners [1,3]. The system also helped maintain the ideal environmental conditions for the Rose Plant, which required regular watering and humidity control to avoid fungal diseases. Similarly, the Money Plant, which thrives in moderate humidity, was consistently monitored, ensuring it grew in optimal conditions. Another advantage was the low-maintenance nature of the system. Once the sensors were installed and configured, they functioned continuously without any major issues. The system's ability to save time and effort was also appreciated, as users no longer had to manually check soil moisture or monitor temperature and humidity levels [11]. However, the system has its limitations. The biggest limitation is its dependence on a stable power supply and Wi-Fi connection, as the system cannot function properly during power or internet outages. Additionally, the system requires frequent calibration to ensure sensor accuracy, and a minor error in sensor readings could trigger unnecessary watering or insufficient care [15]. Another limitation is the cost of setting up such a system, which could be a barrier for users with multiple plants or a limited budget.

7. Conclusion and Future Work

This research demonstrated the effectiveness of an IoT-based system in monitoring and maintaining ideal growing conditions for Aloe Vera, Rose Plant, and Money Plant [16]. It automated watering, tracked real-time environmental data, and reduced manual effort. Future improvements could enhance reliability, scalability, and independence from Wi-Fi and power disruptions.

7.1 Summary of Findings

The IoT-based plant monitoring system effectively monitored and maintained healthy conditions for Aloe Vera, Rose Plant, and Money Plant [2,6]. The setup included soil moisture and DHT11 temperature-humidity sensors, a NodeMCU ESP8266, a relay module, and a small water pump. Each plant was assigned moisture thresholds: Aloe Vera required minimal watering (triggered at <15%), Rose needed moderate moisture (triggered at <40%), and Money Plant required balanced care (triggered at <35%). The system performed consistently, with sensor readings transmitted every few seconds and water delivered only when required. Aloe Vera's moisture levels ranged between 12–25%, Rose Plant between 42–60%, and Money Plant between 32–48%. Temperature and humidity also stayed within each plant's ideal ranges. This system helped avoid common plant care mistakes like overwatering, especially critical for Aloe Vera [3]. The system also ensured that water was used efficiently and that plants were cared for even without constant human monitoring [17]. Overall, the system proved successful in delivering automated, reliable plant care using real-time environmental data. It demonstrated how smart monitoring could be applied to indoor plant management to improve health, reduce manual tasks, and encourage sustainable plant maintenance [11].

7.2 Potential Improvements

While the system functioned effectively, there are several opportunities to enhance its functionality, stability, and intelligence. One current limitation is its dependence on continuous Wi-Fi and power. If either is disrupted, the system's monitoring and automation may pause. A possible improvement would be to include offline data storage using an SD card and integrate a battery backup to ensure uninterrupted operation [4,3]. Though the system already utilizes a web dashboard for real-time monitoring, it can be improved with richer visualizations such as graphs, historical logs, and environmental trends for each plant. Integrating mobile responsiveness would also allow easier access from smartphones, making the system more flexible for users on the go. Currently, watering thresholds are set manually. In the future, the system could incorporate adaptive learning algorithms to adjust these thresholds based on each plant's long-term behavior and sensor data trends [6,2]. This would allow for smarter and more personalized watering routines. The system can also be expanded by adding more types of sensors like light intensity or pH level sensors, enabling a broader analysis of plant health [11]. Notifications via email or push alerts when conditions fall outside the ideal range could further enhance automation and usability, making the system more efficient and proactive [11].

7.3 Scope for Future Research

This project lays the foundation for broader research in smart plant monitoring. One future direction is scaling the system to support multiple plants across larger indoor areas like offices, hotels, or homes [7]. A central hub could manage several NodeMCU modules, forming a smart network that manages diverse plant types efficiently. Personalization can also be explored. Instead of fixed thresholds, future systems could use AI to learn plant behavior over time and adjust watering schedules accordingly. For example, if a Money Plant shows signs of slow growth, the system could modify its moisture level or light exposure [11]. Another promising area is integrating environmental data from weather APIs. This would let the system adapt to changing outdoor conditions. For instance, watering can be delayed on days with high humidity or upcoming rain forecasts (if used near windows or balconies) Camera integration could also support image-based plant health monitoring, using computer vision to detect changes in leaf color or shape, signalling potential issues before they worsen [14,20]. Research could also focus on long-term reliability—how sensors perform over time and how systems can self-calibrate [7,15]. Combining plant care with sustainability goals, such as using solar power or biodegradable components, could further enhance the system's impact in modern green living spaces.

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