

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institute, Affiliated to VTU)
Bull Temple Road, Basavanagudi, Bengaluru - 560019



A Project Report on

“GreenSense: The Complete IoT Solution for Plant Growth and Care Using Machine Vision and AI-Powered Disease Detection”

Submitted in partial fulfilment of the requirements for the award of degree

BACHELOR OF ENGINEERING

IN

INFORMATION SCIENCE AND ENGINEERING

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**Department of Information Science and
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C E R T I F I C A T E

This is to certify that the project entitled "*GreenSense: The Complete IoT Solution for Plant Growth and Care Using Machine Vision and AI-Powered Disease Detection*" is a bona-fide work carried out by **Vishal S (1BM21IS206)**, **Sanat K (1BM21IS150)**, **Shreesha Bhat B (1BM21IS165)** in partial fulfilment for the award of degree of Bachelor of Engineering in **Information Science and Engineering** from **Visvesvaraya Technological University, Belgaum** during the year **2024-2025**. It is certified that all corrections/suggestions indicated for Internal Assessments have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering Degree.

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DECLARATION

Vishal S (1BM21IS206), Sanat K(1BM21IS150), Shreesha Bhat B(1BM21IS165) students of B.E. Information Science and Engineering, B.M.S. College of Engineering, Bangalore - 19, hereby declare that the capstone project entitled "***GreenSense: The Complete IoT Solution for Plant Growth and Care Using Machine Vision and AI-Powered Disease Detection***" is an authentic work carried out under the supervision and guidance of **Dr. Anitha H M, Assistant Professor**, Department of Information Science and Engineering , B.M.S. College of Engineering, Bangalore. We have not submitted the matter embodied to any other university or institution for the award of any other degree.

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ABSTRACT

GreenSense is an innovative IoT-based smart plant monitoring system designed for garden pot plants. Utilizing ESP32 microcontrollers, ESP32-CAM modules, Docker containers, and cloud integration, the system monitors various environmental parameters like temperature, humidity, soil moisture, and light intensity in real-time. GreenSense aims to optimize plant health, automate irrigation, and detect plant diseases early, ensuring a sustainable and efficient gardening experience for domestic gardeners.

The primary motivation behind GreenSense is to address common challenges in traditional gardening, such as inefficient water usage, late detection of plant diseases, and the lack of continuous monitoring. By integrating advanced technologies, GreenSense offers a comprehensive solution that enhances plant care and promotes sustainable practices.

The GreenSense web application, along with the Blynk app interface, serves as a user-friendly platform that allows users to monitor plant health, receive alerts, and control the system remotely. The applications provide real-time insights into environmental conditions and set automated irrigation schedules based on soil moisture and temperature data. Additionally, users receive notifications when water levels are low, ensuring timely refilling of the water storage tank integrated beneath the plant pot.

GreenSense is designed to be scalable and self-sustaining, with the capability to support multiple plants and larger garden setups. The system is powered by rechargeable batteries and solar panels, ensuring continuous operation and reducing reliance on external power sources.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Traditional home gardening often involves manual labor and guesswork, resulting in inefficiencies in plant care, such as overwatering, under-watering, or inconsistent monitoring of environmental factors. Many plant owners face challenges in ensuring optimal growth conditions due to a lack of real-time data on soil moisture, temperature, humidity, and light. Furthermore, detecting plant diseases and predicting plant yield is often beyond the expertise of casual gardeners, leading to preventable plant health issues and reduced satisfaction with gardening efforts. These limitations can make home gardening a time-consuming and resource-intensive task, deterring people from pursuing it as a hobby or a sustainable lifestyle choice.

To tackle these challenges, our project introduces an innovative IoT-based smart plant care system tailored for home use. This system employs Arduino-powered sensors to continuously monitor key parameters such as soil moisture, temperature, light, and humidity. It automates irrigation by analyzing real-time data to deliver the right amount of water based on environmental conditions, significantly reducing water wastage. A camera module integrated with a convolutional neural network (CNN) identifies early signs of plant diseases, ensuring timely interventions and preventing the spread of harmful conditions. The system also incorporates algorithms for yield prediction, offering users insights into plant growth and productivity over time.

All collected data is transmitted to the cloud, where it is processed and made accessible to users via a user-friendly mobile app or web interface. Through this platform, users can receive real-time alerts, monitor historical trends, and customize system settings to suit their specific plant care needs. The system is powered sustainably by a solar panel and rechargeable battery, ensuring uninterrupted operation even in off-grid scenarios. Additionally, it is designed to be scalable, enabling communication between multiple Arduino units to support larger home gardens or indoor plant setups.

This solution combines advanced technology with convenience, empowering users to maintain thriving plants with minimal effort. It promotes resource efficiency, reduces the need for manual intervention, and fosters a deeper connection between users and their plants. By bringing precision and sustainability to home gardening, this system transforms the way plants are cared for, offering a smarter, eco-friendly, and more enjoyable gardening experience.

The system is self-sustaining, powered by a solar panel and rechargeable battery, ensuring continuous operation with minimal maintenance. It is also scalable, allowing multiple units to communicate with one another for monitoring larger gardens. This innovative solution brings precision, convenience, and sustainability to home gardening, enabling users to enjoy healthier plants, reduced resource wastage, and a smarter approach to plant care.

1.2 Motivation

The growing interest in sustainable living and efficient home gardening inspires our motivation to create an intelligent IoT-based plant monitoring and care system. Traditional home gardening practices often rely on manual methods, leading to inefficient resource usage, inconsistent care, and missed opportunities to optimize plant health. Overwatering, delayed responses to diseases, and inadequate environmental monitoring can harm plant growth while wasting water and other resources. With advancements in IoT and AI, we saw an opportunity to transform home gardening by introducing a smart, precise, and autonomous solution. By integrating real-time monitoring of environmental factors, automated irrigation, and disease detection using CNNs, the proposed system ensures optimal plant care with minimal user intervention. Solar-powered operation further supports eco-friendly innovation, reducing reliance on conventional energy sources. Our ambition is to empower home gardeners with a sustainable, efficient, and technologically advanced tool to enhance the joy and success of gardening while promoting resource conservation.

1.3 Objective

The **GreenSense Project** is designed to provide an affordable, sustainable, and scalable solution for urban and terrace gardeners, as well as small-scale farmers, promoting efficient plant care using IoT and Machine Vision technologies.

Key Objectives:

1. Sustainable Urban Gardening:

- Empower urban and terrace gardeners with an intelligent plant care system that requires minimal manual intervention.
- Optimize water usage through real-time monitoring and automated irrigation, promoting water conservation and efficient resource management.
- Provide gardeners with actionable insights into plant health, enabling better care and fostering a deeper connection between users and their plants.

2. AI and Machine Vision for Plant Health:

- Leverage machine learning and machine vision to detect plant diseases in their early stages, preventing the spread of infections and ensuring healthier plants.
- Provide tailored care recommendations to optimize fertilizer use and reduce wastage of agricultural inputs.
- Enhance plant productivity and growth through precise monitoring of environmental factors like light, temperature, humidity, and soil moisture.

3. Scalable Agricultural Solutions:

- Develop a modular system capable of scaling up for use in larger agricultural settings, addressing the needs of small-scale farmers.
- Enable data-driven farming through IoT sensors and cloud-based analytics, providing insights into soil health, environmental conditions, and yield predictions.
- Create a system that fosters collaboration between multiple units, allowing large-scale monitoring and management across expansive farms.

4. Economic Empowerment and Innovation:

- Deliver a cost-effective and user-friendly technology that bridges the gap between traditional farming practices and modern smart agriculture.
- Empower small-scale farmers and home gardeners to enhance productivity and profitability using accessible technology.
- Foster innovation by integrating IoT, AI, and renewable energy sources, setting the stage for further advancements in plant care solutions.

5. Self-Sustainability and Environmental Impact:

- Incorporate solar panels and rechargeable batteries to ensure the system operates sustainably, reducing reliance on conventional power sources.
- Minimize environmental impact by promoting resource efficiency and reducing waste through automated, precision-based interventions.
- Encourage sustainable living by providing a system that aligns with eco-friendly practices and supports greener urban and rural environments.

By combining IoT, Machine Vision, and AI with sustainable design principles, the GreenSense Project aims to redefine how plants are cared for in homes, gardens, and farms. Its modular, self-sustaining approach ensures that the system can adapt to a wide variety of use cases, from urban gardening in small spaces to large-scale farming operations. Ultimately, the project envisions a future where advanced technology enables individuals and communities to embrace smarter, more sustainable, and highly productive gardening and farming practices.

1.4 Scope

The scope of the proposed system integrates IoT, machine vision, sustainable technology, and smart gardening practices. Below are the key aspects of the project's scope:

1. Design and Development of Monitoring and Care System

- Develop a modular, lightweight system using Arduino boards, sensors, and essential components like water pumps for efficient plant monitoring and care.

- Ensure ease of installation and compatibility with urban home gardens, terrace gardens, and indoor plant setups.

2. Real-Time Environmental Monitoring

- Incorporate sensors to monitor soil moisture, temperature, humidity, and light levels in real time.
- Collect and process environmental data to ensure optimal growing conditions for plants and minimize resource wastage.
- Adapt the system to various environmental settings, from small indoor spaces to larger terrace gardens.

3. Sustainable Power Usage

- Utilize solar panels and rechargeable batteries to power the system, reducing dependency on traditional energy sources.
- Promote environmental sustainability by enabling self-sustaining operation with minimal maintenance requirements.

4. Machine Vision for Plant Health Analysis

- Implement a convolutional neural network (CNN) for real-time plant health analysis through an integrated camera module.
- Detect early signs of plant diseases, classify plant health status, and provide actionable recommendations for care and treatment.
- Train the model using a diverse dataset to ensure high accuracy and adaptability to different plant types.

5. Automated Irrigation and Care

- Design an automated irrigation mechanism that adjusts water delivery based on soil moisture and environmental data.
- Optimize water usage to prevent overwatering or under-watering, promoting resource efficiency and healthier plant growth.

6. Scalability and System Expansion

- Develop a modular and scalable architecture that supports communication between multiple Arduino units.
- Enable the system to be expanded for use in larger home gardens.

7. User-Friendly Monitoring and Interaction

- Design a mobile application or web interface for real-time monitoring and control of the system.
- Provide users with insights such as environmental trends, plant health updates, and irrigation schedules.
- Enable remote notifications and alerts for critical issues like low moisture, detected diseases.

8. Eco-Friendly Practices and Impact

- Reduce environmental impact by minimizing water and fertilizer wastage through precise interventions.
- Foster sustainable home gardening practices and encourage users to adopt smart, eco-conscious approaches to plant care.

The proposed system offers a comprehensive and intelligent solution to automate and optimize plant care for home gardens, terrace setups, and small-scale applications. It combines technology, sustainability, and ease of use, making smart gardening accessible to all.

1.5 Existing System

Traditional methods of plant monitoring and care in garden pot plants largely rely on manual observation and intervention. Gardeners typically assess plant health by visually inspecting the plants and feeling the soil to determine moisture levels. Based on these observations, they manually water the plants, adjust their positions for optimal sunlight, and apply fertilizers as needed. While this method has been used for centuries, it is inherently inefficient and labor-intensive, often leading to suboptimal plant health and resource usage.

Challenges in Traditional Methods:

1. **Inefficient Water Usage:** Manual watering often results in either overwatering or underwatering, which can harm plant health. Overwatering can lead to root rot and

fungal diseases, while underwatering can cause dehydration and stunted growth.

2. **Lack of Real-time Monitoring:** Traditional methods do not provide continuous monitoring of environmental parameters, making it difficult to respond promptly to changes in temperature, humidity, or soil moisture.
3. **Delayed Disease Detection:** Visual inspection may not identify early signs of diseases, leading to delayed intervention and potential spread of diseases that can devastate the plants.
4. **Labor-intensive:** Regular manual checks and interventions are time-consuming and require consistent effort from the gardener.
5. **Inconsistent Care:** Variability in the gardener's attention and knowledge can lead to inconsistent care, affecting plant health and yield.

Existing Automated Systems: Several automated plant monitoring systems have been developed to address some of these challenges. These systems typically incorporate sensors to measure environmental parameters such as soil moisture, temperature, and humidity. Data from these sensors is used to automate irrigation and provide alerts to the gardener. However, existing systems have limitations:

1. **Limited Integration:** Many systems focus solely on irrigation control and do not provide a holistic view of plant health, including disease detection and overall growth conditions.
2. **Lack of Cloud Integration:** Some systems do not leverage cloud services for data storage and analysis, limiting the ability to access historical data and make data-driven decisions.
3. **Basic Automation:** The automation provided by existing systems is often basic, with limited capabilities for advanced functions like image processing for disease detection and machine learning for predictive insights.
4. **User Interface:** Many existing systems have non-intuitive interfaces, making it difficult for users to interact with the system and access critical information.

Conclusion: While existing systems have made strides in automating some aspects of plant care, there is a need for a more comprehensive solution that integrates real-time monitoring, advanced data analysis, and user-friendly interfaces. GreenSense aims to address these gaps by providing a complete smart plant monitoring system that enhances plant health, optimizes resource usage, and offers a self-sustaining solution for domestic gardeners.

GreenSense will integrate sensors for various environmental parameters, employ machine learning for disease detection, utilize cloud services for data analysis, and offer a user-friendly web application for remote monitoring and control, thus providing a significant improvement over traditional and existing automated systems.

1.6 Proposed System

The proposed system, named "GreenSense," is an IoT-based smart plant monitoring solution specifically designed for garden pot plants. GreenSense aims to address the challenges of traditional plant care by integrating advanced technologies to provide real-time monitoring, automated irrigation, and early disease detection. The system leverages ESP32 microcontrollers, ESP-NOW protocol, Docker containers, and cloud integration to deliver a comprehensive and efficient plant care solution.

System Components:

1. ESP32 Microcontrollers and ESP32-CAM:

- The system employs ESP32 microcontrollers equipped with various sensors, including temperature, humidity, soil moisture, and light intensity sensors, to continuously monitor environmental conditions.
- The ESP32-CAM module captures images of plant leaves to detect diseases using machine learning algorithms.

2. Wireless Communication:

- The ESP-NOW protocol enables efficient, low-power communication between multiple ESP32 nodes, ensuring seamless data transmission within the system.

3. Central Coordinator Node:

- A central ESP32 node aggregates data from all sensor nodes and forwards it to the cloud using Wi-Fi. This node acts as the system's data hub.

4. Cloud Services and Docker Containers:

- Data collected by the central node is sent to the cloud, where Dockerized services handle data storage, processing, and analysis.
- A data collection service receives sensor data and stores it in a cloud database.

- A machine learning service processes images to detect plant diseases, leveraging pre-trained models for accurate analysis.

5. Web Application:

- A user-friendly web application provides a platform for users to monitor plant health, receive alerts, and control the system remotely. The application displays real-time data and insights, allowing users to make informed decisions about plant care.

6. Automated Irrigation System:

- Based on real-time soil moisture and temperature data, the system controls water pumps to automate irrigation, ensuring optimal water usage and plant health.
- A water storage tank integrated beneath the plant pot captures excess water, which is recycled for future irrigation, promoting sustainability.

7. Notification System:

- Users receive notifications via the web application when certain thresholds are exceeded, such as low water levels in the storage tank.

Benefits and Outcomes:

- **Enhanced Plant Health:** Continuous real-time monitoring and timely interventions ensure optimal conditions for plant growth.
- **Resource Optimization:** Automated irrigation based on sensor data reduces water wastage and conserves resources.
- **Early Disease Detection:** The integration of image processing and machine learning enables early detection of plant diseases.
- **User Convenience:** The web application provides a convenient interface for remote monitoring and control, making plant care more accessible and manageable.
- **Sustainability:** The system's ability to recycle excess water and use solar power for operation promotes environmentally sustainable practices.
- **Scalability:** GreenSense is designed to be scalable, supporting multiple plants and larger garden setups, making it suitable for various gardening needs.

In conclusion, GreenSense offers a comprehensive, efficient, and scalable solution for smart plant monitoring and management in garden pot plants. By leveraging IoT, cloud services, and machine learning, GreenSense addresses the limitations of traditional plant

care methods and provides a sustainable and user-friendly approach to gardening.

CHAPTER-2

PROBLEM STATEMENT

2.1 Problem Statement

Traditional methods of caring for garden pot plants rely heavily on manual observation and intervention, which can often be time-consuming and inefficient. Gardeners typically assess plant health by visually inspecting the plants and feeling the soil to determine moisture levels. Based on these observations, they manually water the plants, adjust their positions for optimal sunlight, and apply fertilizers as needed. While these practices have been used for generations, they present several challenges:

1. **Inefficient Water Usage:** Manual watering can result in either overwatering or under watering, both of which can harm plant health. Overwatering can lead to root rot and fungal diseases, while under watering can cause dehydration and stunted growth.
2. **Lack of Real-Time Monitoring:** Traditional methods do not offer continuous monitoring of environmental conditions such as temperature, humidity, and soil moisture. This makes it difficult to respond promptly to changing conditions that may affect plant health.
3. **Delayed Disease Detection:** Relying on visual inspection alone may not identify early signs of plant diseases, leading to delayed interventions that could exacerbate the problem and potentially spread to other plants.
4. **Labor-Intensive:** Manual care requires regular attention and effort from the gardener, which may not always be feasible, especially for individuals with busy schedules.
5. **Inconsistent Care:** Variability in a gardener's attention and expertise can result in inconsistent plant care, affecting plant health and growth.

These challenges highlight the need for an automated system that provides real-time monitoring, efficient resource management, and early disease detection to ensure optimal plant care for garden pot plants.

2.2 Motivation

The motivation behind GreenSense arises from the desire to address the inefficiencies and challenges associated with traditional gardening methods for pot plants. Key motivations include:

1. **Improving Plant Health:** By providing real-time monitoring of environmental parameters, GreenSense ensures that plants receive optimal care, promoting healthier growth and reducing the likelihood of diseases.
2. **Optimizing Resource Usage:** Automated irrigation based on sensor data helps to conserve water by ensuring plants receive the right amount of moisture. This not only benefits plant health but also promotes sustainable water usage.
3. **Enhancing User Convenience:** GreenSense aims to reduce the labor-intensive nature of traditional gardening by automating key tasks such as watering and disease detection. This allows gardeners to focus on other aspects of plant care and enjoy their gardening experience.
4. **Early Disease Detection:** Utilizing image processing and machine learning, GreenSense can detect plant diseases early, allowing for timely interventions that can prevent the spread of diseases and minimize damage.
5. **Scalability and Adaptability:** GreenSense is designed to be scalable, supporting multiple plants and larger garden setups. The system's adaptability ensures that it can be customized to meet the specific needs of different users and gardening environments.
6. **Promoting Sustainable Gardening:** By integrating renewable energy sources such as solar panels and recycling excess water, GreenSense promotes environmentally friendly practices that contribute to sustainable gardening.

Overall, the motivation for GreenSense is to leverage modern technology to create an intelligent and efficient plant monitoring system that addresses the limitations of traditional methods and enhances the overall gardening experience.

2.3 Objectives

The primary objectives of the GreenSense project are as follows:

1. Real-Time Environmental Monitoring:

- To continuously monitor key environmental parameters such as temperature, humidity, soil moisture, pH, and light intensity using ESP32 sensors. This will ensure optimal conditions for plant health and provide data for informed decision-making.

2. Automated Irrigation Control:

- To develop an automated irrigation system that uses real-time sensor data to determine the appropriate watering schedule for garden pot plants. This will optimize water usage, prevent overwatering and underwatering, and reduce the need for manual intervention.

3. Early Disease Detection:

- To implement image processing and machine learning algorithms using the ESP32-CAM to capture and analyze images of plant leaves. This will enable early detection of plant diseases, allowing for timely interventions and minimizing potential damage.

4. User-Friendly Interface:

- To create a web application that provides a user-friendly interface for remote monitoring and control. The application will display real-time data, historical trends, and notifications, allowing users to make informed decisions about plant care.

5. Scalability and Self-Sustainability:

- To design a system architecture that supports scalability, enabling the monitoring and management of multiple plants and larger garden setups. The system will also incorporate renewable energy sources such as solar panels and rechargeable batteries to ensure continuous operation and promote sustainable gardening practices.

By achieving these objectives, GreenSense aims to provide a comprehensive solution for smart plant monitoring and management, enhancing plant health, optimizing resource usage, and offering a scalable and self-sustaining system for domestic gardeners.

CHAPTER-3

DETAILED SURVEY

[1] “A Review on Smart Plant Monitoring System” [Ashwini Patil, Ashwini Mali]

Agriculture remains vital to India's economy, but it faces significant challenges, particularly in water management, as traditional irrigation methods waste water and contribute to environmental degradation. These challenges are exacerbated by unpredictable weather patterns caused by climate change. Therefore, there is a need for more efficient, automated irrigation systems that conserve water while ensuring optimal crop growth.

Traditional irrigation techniques, such as flood irrigation, often waste water, either over-irrigating or under-irrigating crops. These methods can lead to soil erosion, nutrient loss, and excessive labor. The proposed system addresses these issues by using modern technologies like sensors, microcontrollers, and wireless communication to automate irrigation based on real-time environmental data. The system uses soil moisture, temperature, and humidity sensors to monitor conditions and adjust irrigation automatically, ensuring plants receive the right amount of water at the right time.

The system consists of three main components: a sensing module, a controller module, and an output module. The sensing module collects data on soil moisture, temperature, and humidity, which are transmitted to the microcontroller. The microcontroller processes this data, compares it to predefined thresholds, and sends signals to activate the water pump or other systems when necessary. The output module includes a water pump to irrigate the plants and an indicator system that alerts users to the status of the system.

Communication technologies such as GSM and Bluetooth enable remote monitoring and control. GSM sends real-time updates and alerts to farmers' mobile phones, while Bluetooth allows for local communication, enabling farmers to monitor and control the system without internet access.

The key advantage of this system is its ability to optimize water usage. Unlike traditional methods that apply water uniformly regardless of need, this system uses precise data to

irrigate only when necessary, conserving water and improving efficiency. Furthermore, the system operates autonomously, reducing the need for manual intervention and allowing farmers to focus on other aspects of farm management. Remote monitoring also provides greater flexibility for farmers to adjust irrigation settings from anywhere.

Additionally, the system could incorporate predictive analytics by analyzing historical data to predict when irrigation will be needed. This would further optimize water usage and prevent unnecessary irrigation.

However, there are challenges to be addressed. The system must be reliable and robust in various environmental conditions, and the cost of implementation could be a barrier for small-scale farmers. Sensor accuracy and regular calibration are also essential to ensure optimal system performance.

In conclusion, this smart irrigation system offers a more efficient and sustainable solution to the challenges of water scarcity and inefficient irrigation in agriculture. By automating the irrigation process and using real-time data, it reduces water waste, improves crop yields, and lowers labor costs. Despite challenges in cost, reliability, and sensor accuracy, the system's potential to conserve water and enhance farming practices is immense. With further development, it could play a key role in transforming agriculture toward more sustainable practices.

[2] “A Smart System for Garden Watering using Wireless Sensor Networks”
[Constantinos Marios Angelopoulos Sotiris Nikoletseas, Georgios Constantinos Theofanopoulos]

The paper focused on the development of a smart irrigation system aimed at improving water efficiency and sustainability in agriculture. Using a wireless sensor network (WSN), the system was designed to monitor soil moisture levels in real-time and adjust the irrigation process based on the specific water needs of each plant. The system combined soil moisture sensors, wireless motes, and electro-valves, all controlled through a central Java application, to ensure optimal water usage and minimize waste.

The sensor motes, which were equipped with EC-5 soil humidity sensors, were responsible for measuring the moisture content of the soil in each plant pot. These readings were then transmitted wirelessly to a central control unit, which processed the data and triggered the

electro-valves when the soil moisture fell below a predefined threshold. The electro-valves, controlled by the system, were used to regulate the amount of water dispensed, ensuring that only the necessary amount of water was applied. This method of irrigation not only conserved water but also helped prevent over-irrigation, which can damage plants and waste valuable resources.

The system's central Java application played a crucial role in managing the irrigation process. It collected data from the sensor motes, stored it in a MySQL database, and allowed users to monitor soil moisture levels remotely. The application provided real-time feedback, allowing users to track the health of their plants and adjust watering schedules as needed. Furthermore, the system was designed to be flexible, enabling users to fine-tune settings such as moisture thresholds and watering frequencies based on the specific needs of different plant species.

The paper also highlighted the importance of wireless communication in the system. The motes communicated via the ZigBee protocol, which provided reliable, low-power, and secure data transmission over short distances. This made the system suitable for deployment in garden environments, where power outlets may not be available. The use of ZigBee also minimized the risk of interference from other wireless devices, ensuring stable communication between the motes and the central control unit.

Field tests of the smart irrigation system were conducted using three different plant species: geranium, lavender, and mint. These plants were chosen because they have varying water requirements, making them ideal for testing the system's ability to adapt to different irrigation needs. The results showed that the system effectively maintained optimal soil moisture levels for all three plant species. For instance, the geranium, which requires minimal watering, was watered less frequently, while the mint, which has higher water needs, was watered more often. The system successfully adjusted the irrigation frequency for each plant, ensuring that each received the appropriate amount of water.

Overall, the smart irrigation system demonstrated the potential to revolutionize agricultural practices by integrating IoT technologies and wireless communication. By automating the irrigation process and optimizing water usage, the system not only helped farmers save water and reduce costs but also contributed to more sustainable and environmentally friendly farming practices. The system's remote monitoring capabilities and flexible design

further enhanced its usability, making it an effective tool for farmers seeking to improve water efficiency and optimize plant growth.

[3] “A Study on IoT based Real-Time Plants Growth Monitoring for Smart” [Mi-Hwa Song]

This paper presents a solution to address various challenges in agriculture using IoT-based technology. The aim is to develop a smart garden system capable of real-time monitoring of environmental conditions, such as humidity, temperature, air quality, and soil moisture. By integrating IoT sensors, the system automates irrigation processes based on the moisture content of the soil and climatic conditions. This reduces manual intervention, ensuring efficient water usage and enhancing crop growth. The system also features a user-friendly interface, allowing farmers to remotely monitor the data collected by the sensors and make informed decisions.

The system's hardware design relies on open-source components, including a NodeMCU microcontroller and various environmental sensors such as the DHT11 for temperature and humidity, MQ135 for air quality, and a soil moisture sensor. The data is processed by the NodeMCU and transmitted to a cloud server (Google Firebase) for real-time monitoring. Additionally, the system is capable of automating outputs such as water pumps, fans, and LED lamps to maintain optimal conditions for plant growth.

The project successfully demonstrates the potential of IoT in enhancing agricultural practices by automating monitoring and irrigation, improving efficiency, and promoting sustainable farming. Future improvements include adding pH sensors to monitor soil acidity and the integration of a fertilizer pump to further optimize plant care. The system is a step toward reducing the dependency on manual labor and ensuring better resource management in agriculture.

[4] “A Novel Approach to IoT Based Plant Health Monitoring” [Srinidhi Siddagangaiah]

The paper focuses on developing an IoT-based plant health monitoring system aimed at improving agricultural practices. The system utilizes sensors to track key environmental factors like temperature, humidity, soil moisture, and light intensity, which are crucial for plant growth. These sensors, such as the DHT11 for temperature and humidity, YL-38 for

soil moisture, and TEMT6000 for light intensity, provide real-time data to a cloud platform, Ubidots, via an Arduino microcontroller. This setup allows farmers to remotely monitor and control the environmental conditions of their crops.

By integrating IoT technology, the system automates the collection of data from sensors and stores it in the cloud for easy access and analysis. The cloud platform enables users to visualize the data in the form of dashboards and graphs, providing actionable insights to optimize plant health. Through this system, farmers can receive alerts when environmental factors deviate from ideal conditions, allowing them to take timely action to improve crop yield.

The use of this system offers several benefits, including the ability to monitor crops from remote locations, reduce manual effort, and optimize the use of resources like water and light. This approach also contributes to precision agriculture, where data-driven decisions lead to more sustainable farming practices. Field tests have shown that the system effectively monitors plant health and provides valuable feedback for improving agricultural outcomes. Overall, the system supports smarter, more efficient farming, ultimately increasing productivity and reducing resource wastage.

[5] “**An IoT Controlled System for Plant Growth**” [Boonsit Yimwadsana , Pichamon Chantrapeth , Chanyanuch Lertthanyaphan, Antika Pornvechamnuay]

The paper discusses the traditional approach to farming in which farmers rely on personal experience and ancestral knowledge rather than a scientific process or continuous improvement. It highlights how farming production is significantly influenced by environmental conditions such as air temperature, humidity, light intensity, and soil moisture. Farmers aim to create optimal conditions to maximize output and quality, but this is often done without precise tools or methodologies. The paper introduces Smart Farming as a solution to this challenge, leveraging modern technologies like the Internet of Things (IoT) to enable real-time monitoring and remote control of farming environments. While globally Smart Farming has been widely adopted due to its precision and efficiency, the paper notes that in Thailand, barriers such as limited financial investment, technical knowledge, and skill in deploying IoT devices have prevented widespread adoption.

According to the paper, addressing these barriers is essential for Thai farmers to benefit

from technology that can reduce costs, minimize waste, and make farming more efficient and enjoyable. The proposed system, as outlined in the paper, aims to create an easy-to-use environment for farmers by integrating sensors, actuators, and management software into a black-box solution that simplifies installation and use. The paper describes how sensors monitor key environmental variables, including air temperature, humidity, light intensity, and soil moisture, with the data analyzed to optimize conditions for plant growth. The system can adjust conditions automatically, such as controlling sprinklers or retracting a roof, based on rule-based models developed through multivariate data analysis.

The hardware components detailed in the paper include DHT11 air temperature and humidity sensors, YL-69 soil moisture sensors, GL5516 light intensity sensors, relays, motors, water pumps, and sprinklers, all managed by Raspberry Pi and Arduino platforms. The software implementation uses Apache, HTML, PHP, CSS, JavaScript, Python, and MySQL to provide a user-friendly dashboard for real-time monitoring and control. Farmers can manually adjust conditions or rely on automation. Experiments described in the paper focus on sensor calibration, scientific studies of plant growth under controlled conditions, and the engineering of reliable actuator systems. The paper concludes that this system represents a practical solution to improve productivity, crop quality, and cost-efficiency, providing Thai farmers with the tools to transition into technology-driven farming practices.

[6] “Automatic IoT Based Plant Monitoring and Watering System using Raspberry Pi” [Anusha k , Dr. U B Mahadevaswamy]

The project focuses on an IoT-based automatic plant monitoring and watering system using Raspberry Pi. The primary aim is to help Indian farmers transition from traditional methods to modern agriculture practices, improving crop yield with reduced manual effort. The system integrates sensors to monitor environmental conditions like temperature, humidity, soil moisture, and light intensity, sending data to a server for real-time analysis. A web application displays sensor results, enabling farmers to monitor and control the system remotely. The Raspberry Pi serves as the central processor, utilizing Python programming to interface with sensors and manage the system.

The system's hardware components include the Raspberry Pi (Model B 3.1), temperature, humidity, moisture, light, and IR sensors. These sensors monitor various environmental

factors that affect plant growth. The system also uses a motor controlled by a relay, which turns on or off based on soil moisture levels. The IR sensor detects intruders, triggering a buzzer when an intruder is detected. The system's operation is controlled through a web interface, where users can access the data and manage the watering system.

In terms of advantages, the proposed system offers several improvements over existing solutions. It utilizes a Raspberry Pi, which provides better memory and processing power compared to traditional microcontrollers. The use of IoT technology enables remote monitoring, which enhances accessibility and security. The system is also more scalable, with the ability to add more sensors as needed. Moreover, it presents data both numerically and in statements, making it easier for farmers to interpret. The implementation of a secure web application ensures safe communication, and the system can be accessed by anyone with the correct credentials.

However, there are some limitations. The system's effectiveness is dependent on internet connectivity, which may be a challenge in remote areas. Additionally, while the system is relatively low-cost, the initial setup may still be out of reach for some farmers, especially those with limited resources. The system also requires basic technical knowledge to operate, which might be a barrier for some users.

In conclusion, the IoT-based monitoring and watering system for plants represents a significant step toward modernizing agriculture. By integrating sensors and IoT technology, the system provides real-time data and remote control, helping farmers improve crop yield with minimal manual labor. The use of Raspberry Pi and IoT enhances scalability and accessibility, while the web-based application allows for easy monitoring and management. This approach could contribute to increased agricultural productivity and economic growth in rural areas, although challenges such as internet access and affordability need to be addressed.

[7] “Deep learning based computer vision approaches for smart agricultural applications” [V.G. Dhanya,A. Subeesh,N.L. Kushwaha,Dinesh Kumar, Vishwakarma,T. Nagesh Kumar,G. Ritika,A.N. Singh]

The UNDP 2021 report emphasizes that global food production must increase by 98% by 2050 to meet the demands of the growing world population. This projection highlights the

urgency of transforming agricultural practices to ensure food security while minimizing environmental impact. Precision agriculture, which uses advanced technologies such as artificial intelligence (AI), machine learning, and computer vision, presents an innovative solution to address these challenges. By optimizing farming practices, precision agriculture can significantly improve crop yield, resource management, and sustainability.

AI plays a pivotal role in modernizing agriculture by enabling smarter decision-making. With machine learning algorithms, AI can analyze large amounts of data collected from various sources like satellite imagery, weather reports, and soil sensors. These analyses help predict weather patterns, assess soil conditions, and identify potential crop diseases, ultimately leading to more accurate and timely interventions. Machine learning models can also be trained to identify patterns in crop growth and behavior, offering valuable insights for farmers to make data-driven decisions. This improves overall farming efficiency, reduces resource waste, and helps optimize inputs such as fertilizers and water, which are critical to the environment.

Computer vision, another critical component of precision agriculture, uses deep learning and image processing techniques to enable machines to visually understand and interpret the environment. This technology has revolutionized tasks such as plant health monitoring, pest detection, and crop classification. By analyzing images captured by drones or other imaging devices, AI algorithms can automatically detect early signs of diseases or nutrient deficiencies in plants. The ability to monitor crops in real time, without human intervention, makes this technology particularly valuable for large-scale farming operations where manual inspections would be time-consuming and labor-intensive. Additionally, computer vision can identify weeds, pests, or other obstacles, allowing farmers to apply targeted treatments and reduce the use of chemicals.

The adoption of AI and computer vision in agriculture is also closely tied to the rise of autonomous farming equipment. Autonomous tractors, drones, and harvesters equipped with AI-driven systems can perform tasks such as planting, spraying pesticides, and harvesting with minimal human involvement. These machines use sensors, cameras, and machine learning algorithms to navigate fields, detect obstacles, and optimize operations. This automation not only reduces labor costs but also enhances productivity by ensuring that tasks are performed at optimal times and with precise accuracy.

Overall, the integration of AI and computer vision into agriculture holds great promise for the future of food production. These technologies can optimize farming operations, increase crop yields, and reduce resource consumption, contributing to a more sustainable and efficient agricultural system. As the global population continues to rise, the role of precision agriculture in feeding the world while protecting the planet becomes increasingly vital.

[8] “**Enhancement of Plant Monitoring Using IoT**” [A. Pravin1, T. Prem Jacob and P. Asha]

The Internet of Things (IoT) plays a significant role across various sectors, and agriculture, being a vital industry, is one of the key beneficiaries. With the increasing demand for efficient and sustainable farming practices, IoT can help tackle some of the major challenges faced by the agricultural sector, including water scarcity and inadequate irrigation systems. In many regions, water scarcity, exacerbated by low rainfall and poor water storage systems, has a detrimental impact on crop yield. IoT-based systems offer innovative solutions to optimize irrigation, monitor plant health, and enhance resource usage, thus ensuring higher productivity while preserving valuable resources. This paper presents a solution where IoT devices, including sensors and processors like Raspberry Pi and Arduino, are used to monitor and manage the agricultural environment efficiently. The proposed system collects data related to soil moisture, temperature, light intensity, and crop health, which can be used to enhance the growth of plants, leading to increased productivity and sustainability in farming.

The IoT devices deployed in this system, such as moisture sensors, temperature sensors, and light sensors, help farmers monitor the essential parameters that impact crop growth. By using sensors to measure factors like soil moisture, temperature, and light, the system can provide real-time insights into the condition of the crops. For example, when the moisture level in the soil is low, the system triggers an automatic water pump to irrigate the crops. The data is processed using devices like Raspberry Pi, which handles complex tasks such as data analysis and decision-making. Arduino, on the other hand, interconnects the sensors and performs basic processing tasks. This setup ensures cost-effective monitoring and efficient water management. Additionally, the use of GSM modules enables remote monitoring, so farmers can receive updates on their crops' condition even

when they are far from the farm.

In conclusion, IoT-based systems present a powerful solution to address critical agricultural challenges. Through real-time data collection and processing, these systems optimize resource usage, improve crop health, and increase productivity. The use of affordable and efficient devices such as Raspberry Pi and Arduino in conjunction with sensors offers a practical and scalable approach to modern farming. As IoT technology continues to evolve, it will further enhance the sustainability of agricultural practices, benefiting both farmers and the environment. By empowering farmers with the right tools and information, this system plays a significant role in improving crop yield and contributing to food security.

[9] “**IOT Based Smart Greenhouse Automation Using Arduino**” [Prof. D.O.Shirsath, Punam Kamble, Rohini Mane, Ashwini Kolap, Prof.R.S.More]

The project presented in the paper focuses on automating and monitoring greenhouse environments using IoT-based systems. The goal is to enhance plant growth by continuously monitoring and controlling various environmental factors such as temperature, humidity, light intensity, CO₂ levels, and soil moisture. The system integrates sensors with an Arduino board, which is connected to a graphical user interface (GUI) created using LabVIEW for easy monitoring. The data from the sensors is processed and displayed, allowing for real-time adjustments to the greenhouse environment.

The hardware used includes an Arduino Mega board, sensors such as the DHT11 for humidity, LM35 for temperature, LDR for light intensity, and soil moisture sensors, all of which provide essential data for optimizing plant growth. This system also includes software components for programming the Arduino and displaying sensor data on a web portal using the Internet of Things (IoT). The primary benefits of this approach include the automation of greenhouse operations, reduced labor costs, and the ability to control the environment remotely.

The merits of the system include its low cost, ease of installation, and operation, making it particularly beneficial for small-scale farmers and greenhouse owners. It is also energy-efficient and adaptable for use in various agricultural settings. However, the system's reliance on the IoT and the internet may pose a challenge in areas with unstable internet connectivity. Additionally, while it automates many tasks, the system may still require

occasional manual intervention for maintenance or adjustments.

In conclusion, the project successfully demonstrates how IoT-based automation can improve the efficiency of greenhouse management by monitoring critical environmental factors. It offers a cost-effective solution for enhancing agricultural productivity, particularly in urban or small-scale farming environments. The system provides significant advantages in terms of automation, resource optimization, and remote monitoring, but its dependency on stable internet connectivity could limit its applicability in certain regions.

[10] “**IoT SMART PLANT MONITORING SYSTEM**” [Mrs. Y. Durga Bhargavi, Mukka Manvitha, Y. Umashankar, K. Vijaya Varma, N. Nikhil Reddy]

The Smart Plant Monitoring System leverages camera-based technology, environmental sensors, and data analytics to offer real-time insights into plant health. The system integrates cameras, which capture visual data, and environmental sensors that measure parameters like humidity, temperature, and soil moisture. By analyzing this data, it can detect anomalies, diseases, and stress factors in plants. The system aims to automate plant care by providing proactive alerts through a user-friendly interface, accessible on web and mobile platforms. This approach replaces traditional methods, which are often limited to periodic assessments, by offering continuous monitoring and immediate feedback.

The key components used in this system include a Raspberry Pi, webcam, regulated power supply, DHT11 sensor, relay module, submersible water pump, soil moisture sensor, and the Blynk app for remote monitoring. A literature survey highlights advancements in plant disease detection using image processing, machine learning, and deep learning techniques, as well as the growing role of AIoT (Artificial Intelligence of Things) in smart agriculture.

The merits of the system include its ability to continuously monitor plant health, detect issues early, and provide timely interventions. The integration of sensors and cameras allows for a more comprehensive understanding of plant conditions, while the automated alert system aids in decision-making. It also fosters sustainable plant care practices by enabling informed and proactive plant management. However, the system's reliance on technology may pose challenges in terms of cost and accessibility for some users. Additionally, the effectiveness of image processing and machine learning models may vary depending on the quality of data and environmental conditions.

In conclusion, the Smart Plant Monitoring System represents a significant step forward in plant care, combining real-time monitoring, automated anomaly detection, and user-friendly interfaces to improve plant health management. This system not only addresses current challenges in plant care but also paves the way for a future where technology and nature coexist harmoniously, driving efficiency, sustainability, and innovation in agriculture.

[11] “**IoT-powered Real Time Smart Plant Surveillance System for Digital Gardening and Agriculture**” [K Subhashini, R D Kalaimathy, K Shreya Shree, R Deepika, R Lakshmi Devi, A Abirami, Dr. J Thamil Selvi]

The project "Plant Monitoring and Automated Watering System" aimed to address the issue of efficient water use in agriculture by implementing a system to monitor soil moisture levels and notify users when watering is required. The goal was to conserve water while supporting plant growth, especially in areas facing water scarcity or droughts. The project was built using an IoT-based solution with components like the NodeMCU, soil moisture sensor, DC water pump, power relay, and temperature and humidity sensors. These components were integrated with the Blynk app, allowing remote monitoring and control via a smartphone.

The system was designed to be cost-effective and efficient, saving water and labor while maintaining optimal soil conditions for plant growth. The use of real-time data enabled farmers to receive alerts when the soil moisture fell below a set threshold, prompting them to activate the watering system. The approach improved productivity, reduced water waste, and simplified monitoring.

The benefits of the system include efficient irrigation, water conservation, reduced labor costs, and environmental friendliness. It also supports real-time updates, ensuring timely action and minimizing water wastage. However, the system's dependence on accurate sensor calibration and proper maintenance is crucial to its long-term performance. Furthermore, the complexity of integrating various sensors and ensuring reliable communication may present challenges in larger-scale implementations.

The project successfully demonstrated how IoT can enhance agricultural practices by automating irrigation and providing real-time data for informed decision-making. Future

improvements could focus on enhancing sensor accuracy, scalability for larger farms, and expanding the system's capabilities for broader agricultural applications.

[12] “IOT-BASED SMART PLANT MONITORING SYSTEM USING NODEMCU”

[Kishan Gautam Barnwal, Shubh Vishnu Giram, Ramesh Premnath Gupta, Vinit Hasmukh Damani]

The challenge in modern agriculture lies in the inability of farmers to accurately monitor critical environmental parameters such as soil moisture, temperature, and humidity around plants. Traditional methods rely on manual observation and guesswork, leading to inefficient water usage, overwatering, under watering, and potential crop damage. This lack of precision results in resource wastage, reduced crop yields, and increased labor costs. Additionally, pest detection and greenhouse management often lack real-time data integration, making it difficult to maintain optimal growing conditions. Existing solutions are either costly, complex, or lack remote accessibility, making them impractical for small-scale farmers or localized agricultural setups.

The proposed system addresses these challenges using IoT technologies with NodeMCU ESP8266 as the core controller. Key components include capacitive soil moisture sensors for accurate soil hydration measurement, DHT11 sensors for air temperature and humidity monitoring, and a 5V relay module to automate water pumps. Data is transmitted wirelessly to the Blynk IoT platform, enabling real-time monitoring through a user-friendly mobile interface. The Arduino IDE facilitates firmware development, while the system integrates pest detection mechanisms for comprehensive plant health management.

Advantages of this approach include precise automation of irrigation, reducing water waste by up to 30% compared to manual methods. Real-time environmental monitoring enables proactive adjustments, potentially increasing crop yields by maintaining optimal growing conditions. The cloud-based Blynk platform allows remote access from any location, empowering farmers with decision-making support. Energy efficiency is achieved through low-power components, and the modular design permits scalability for different farm sizes.

Limitations include dependency on stable internet connectivity for remote access, which might be challenging in rural areas. Initial setup costs for sensors and IoT infrastructure could be prohibitive for subsistence farmers. Sensor calibration requirements and potential

drift over time may affect long-term accuracy. The system currently focuses on basic parameters, lacking integration with advanced agricultural metrics like soil pH or nutrient levels.

[13] “Machine learning Implementation in IoT based Intelligent System for Agriculture” [Bhanu K N, Jasmine H J, Mahadevaswamy H S]

This project integrates IoT to revolutionize agriculture by enabling remote monitoring and automation of soil moisture, temperature, and electrical conductivity, while automating irrigation to address challenges like water wastage and labor-intensive practices. The system employs sensors and a microcontroller to monitor environmental parameters, with deviations triggering text alerts for timely intervention.

The core hardware includes a NodeMCU-ESP8266 for IoT connectivity, a capacitive soil moisture sensor, a DHT11 temperature and humidity sensor, and a 5V water pump controlled by a relay module. The NodeMCU processes sensor data and transmits it to the Blynk IoT app, enabling real-time monitoring and control. Automation activates the pump when soil moisture drops below a threshold and deactivates it when adequate moisture is detected. The software integrates Blynk for a user-friendly interface and the Arduino IDE for programming.

This system optimizes water usage by automating irrigation based on real-time conditions, reducing water wastage and manual labor. Its precise environmental control improves crop yield, while text alerts ensure system health and efficiency, particularly in controlled environments like greenhouses.

Results highlight improved water efficiency, reduced labor, and enhanced crop productivity. The project promotes sustainability and precision agriculture, offering a cost-effective, reliable solution for modern farming practices.

[14] “Novel IoT-Based Plant Monitoring System” [Muhammad Haashir Absar, Ghulam Fiza Mirza, Youail John]

This study addresses the challenges faced by conventional greenhouses, such as limited smart environments, plant diseases, soil degradation, and resource scarcity, which result in

decreased crop production. It proposes an IoT-based Smart Plant Monitoring System that collects data from sensors like the DHT-11 temperature and humidity sensor and soil moisture sensors. The system transmits this data through an ESP-8266 Wi-Fi module to the Blynk IoT platform for remote monitoring and control. Users can monitor real-time data on temperature, humidity, and soil moisture, and take corrective actions, such as activating sprinklers, remotely via a mobile app.

The system's main advantages include reduced labor costs by automating monitoring, water-saving features through remote control, and the ability to optimize plant growth conditions. Additionally, it provides a cost-effective solution for greenhouse automation with a user-friendly mobile interface. However, the system has some disadvantages, such as reliance on Wi-Fi for data transmission and remote control, and limited scalability for large-scale agricultural operations due to its dependence on IoT devices.

[15] “Smart Irrigation and Monitoring System for Pot Plant” [Gan Yaw Kiat, Mohammad Faiz Liewabdullah]

This study presents a Smart Irrigation and Monitoring System for potted plants, aiming to simplify the daily task of watering plants while ensuring their health and growth. The system utilizes an Arduino Uno microcontroller to coordinate various processes such as irrigation, pH monitoring, and water level detection. By employing sensors like soil humidity, pH, and ultrasonic sensors, the system provides real-time data to users through the Blynk application, allowing them to monitor their plants remotely and take necessary actions like fertilizing or refilling water. The research highlights the challenges faced by gardeners, such as managing soil pH and moisture levels, and proposes an automated solution to address these issues effectively.

The system's key advantages include automated watering, real-time health monitoring, and ease of use through the Blynk app, which notifies users of pH value deviations and low water levels. This approach saves time and ensures plants receive the optimal care they need, especially for busy individuals. However, the system's reliance on Wi-Fi and the potential limitations of the sensors in certain environments may pose challenges in broader applications.

Testing and calibration of the prototype have shown promising results. The system

successfully monitored pH values, soil moisture, and water levels, sending timely alerts to users when intervention was required. The interface on the Blynk app proved user-friendly, allowing easy control and monitoring of the plant's status. Overall, the system demonstrated its ability to enhance plant care and automate key gardening tasks, contributing to healthier plants and optimized growth conditions.

CHAPTER-4

SURVEY SUMMARY TABLE

SL.N O	Title of the Paper	Problem Addressed	Authors Approach / Method	Results
1	Smart Plant Monitoring System <i>Authors: Ashwini Patil, Ashwini Mali</i>	Automating plant care and efficient irrigation	Uses wireless sensors for soil moisture, temperature, and humidity, controlled by Arduino Uno. Automates watering with a pump, provides light with red LED, and alerts users via buzzer, Bluetooth, or GSM.	Enhanced plant health through real-time monitoring and automated irrigation; reduced water wastage and manual intervention
2	A SMART SYSTEM FOR GARDEN WATERING USING WIRELESS SENSOR NETWORKS <i>Authors: Constantinos Marios Angelopoulos, Sotiris Nikoletseas, Georgios Constantinos</i>	Inefficient irrigation, water wastage, and high costs	Wireless Sensor Networks (WSNs) with soil humidity sensors and electro-valves; independent monitoring and watering of each pot; data collection and analysis	Efficient soil humidity maintenance, water conservation, adaptation to environmental changes, optimal watering compared to traditional methods
3	A Study on IoT Based Real-Time Plants Growth Monitoring for Smart Garden <i>Author: Mi-Hwa Song</i>	Unpredictable weather, labor shortages, unmonitored environmental factors	IoT-based platform with NodeMCU (ESP8266 WiFi module) and sensors like DHT11, soil moisture, and MQ135; automated irrigation with a water pump, real-time data transmission to Google Firebase and Raspberry Pi	Successful real-time monitoring and automated decisions; future improvements include adding a pH sensor, fertilizer pump, green computing techniques, and interoperability between IoT devices

4	A Novel Approach to IoT-Based Plant Health Monitoring System <i>Author: Srinidhi Siddagangaiah</i>	Monitoring plant health via environmental parameters	Sensors (DHT11 for temp & humidity, YL-38 for soil moisture, TEMT6000 for light) connected to Arduino Uno; data sent to Ubidots IoT cloud for storage and alerts	Successful real-time monitoring and alerts through Ubidots cloud; remote access to data via customizable dashboard
5	AN IOT CONTROLLED SYSTEM FOR PLANT GROWTH <i>Authors: Boonsit Yimwadsana, Pichamon Chanthapeth, Chanyanuch Lerithanyaphan, Antika Pornvechamnuay</i>	Lack of scientific methods in traditional farming	IoT-based system with sensors (temperature, humidity, light, soil moisture) and actuators; data collection, comparison with ideal model, real-time monitoring, and control via dashboard	Improved farming efficiency and productivity; user-friendly system; significant improvement in plant growth and production; reduced operational costs through automation
6	Automatic IoT-Based Plant Monitoring and Watering System Using Raspberry Pi <i>Authors: Anusha K, Dr. U B Mahadevaswamy</i>	Inefficient traditional agriculture methods and high costs	Raspberry Pi with sensors (temperature, humidity, moisture, light, IR), relay, motor; Python for data processing; web-based application for remote monitoring	Successful real-time data collection, automated irrigation based on soil moisture, intruder detection; improved security, accessible control, and functionality compared to existing systems; future improvements include rainwater harvesting
7	Deep Learning Based Computer Vision Approaches for Smart Agricultural Applications <i>Authors: V.G. Dhanya, A. Subeesh, N.L. Kushwaha, Dinesh Kumar</i>	Challenges in deploying real-time solutions, building quality datasets, and effectiveness of models	Deep learning-based computer vision (CNNs) for seed quality analysis, soil analysis, plant health monitoring, and yield estimation	Improved automation and accuracy in plant health monitoring, weed detection, irrigation management, and yield estimation; integration with UAVs and spectral data enhances solution

	<i>Vishwakarma, T. Nagesh Kumar, G. Ritika, A.N. Singh</i>			effectiveness
8	Enhancement of Plant Monitoring Using IoT <i>Authors: A. Pravin, T. Prem Jacob, P. Asha</i>	Water scarcity, inefficient irrigation, crop diseases	IoT-based system with sensors (temperature, soil moisture, light) and Arduino; automated irrigation control via water pump and relay; real-time updates via GSM	Efficient soil humidity maintenance, water conservation, optimal watering; improved crop yield and productivity through timely interventions
9	IoT Based Smart Greenhouse Automation Using Arduino <i>Authors: Prof. D.O. Shirasath, Punam Kamble, Rohini Mane, Ashwini Kolap, Prof. R.S. More</i>	Challenges in greenhouse management	IoT-based automation system with Arduino and sensors (temperature, humidity, soil moisture, light intensity, CO2); data processing and real-time decisions for irrigation and environmental control; remote monitoring and control via web portal	Successful real-time monitoring and automated control of greenhouse conditions; improved plant growth and productivity; enhanced resource efficiency and reduced labor costs
10	IoT Smart Plant Monitoring System <i>Authors: Mrs. Y. Durga Bhargavi, Mukka Manvitha, Y. Umashankar, K. Vijaya Varma, N. Nikhil Reddy</i>	Traditional plant monitoring methods are inefficient and delay detecting issues like pests, diseases, and environmental stress	IoT cameras and advanced image processing to offer real-time, accurate analysis of plant health	Efficient detection of plant health issues early, enabling timely intervention; user-friendly interface for decision-making; promotes sustainable agriculture

11	IoT-Powered Real-Time Smart Plant Surveillance System for Digital Gardening and Agriculture <i>Authors: K Subhashini, R D Kalaimathy, K Shreya Shree, R Deepika, R Lakshmi Devi, A Abirami, Dr. J Thamil Selvi</i>	Inefficient water management in agriculture, especially in drought-prone areas	IoT-enabled system with soil moisture sensors, DC water pump, NodeMCU microcontroller, Blynk mobile app; automated watering based on real-time soil moisture data	Successful real-time monitoring and automated watering; reduced water wastage, improved plant growth, and optimized resource efficiency
12	IoT-Based Plant Monitoring System Using NodeMCU <i>Authors: B. Sivakumar, M. Manikandan, M. Thamarai Selvi, M. Bhavani</i>	Inefficient irrigation, soil monitoring, and pest detection in agriculture	IoT-based system with ESP8266 microcontroller, capacitive soil moisture sensor, DHT11 sensor for temperature and humidity, 5V relay module, DC water pump; data transmission via Wi-Fi to Blynk app	Successful real-time monitoring and automated irrigation; improved plant health and resource management; future enhancements include rainwater harvesting and green computing techniques.
13	Machine Learning Implementation in IoT Based Intelligent System for Agriculture <i>Authors: Bhanu K N, Jasmine H J, Mahadevaswamy H S</i>	Lack of accurate soil condition data affecting crop yield and resource management	IoT-based system with sensors for soil and environmental monitoring; data sent to ThingSpeak cloud platform; machine learning (Naive Bayes) for data analysis and notifications	Real-time data transmission and smart irrigation; Naive Bayes algorithm achieved 76.47% accuracy; improved decision-making and agricultural productivity

14	<p>Novel IoT-Based Plant Monitoring System</p> <p><i>Authors:</i> <i>Muhammad Haashir Absar, Ghulam Fiza Mirza, Warisha Zakai, Youail John, Noman Mansoor</i></p>	<p>Inefficient, remote monitoring and management of plant health parameters in conventional greenhouses</p>	<p>Sensors (DHT11 for temperature and humidity, soil moisture sensors) collect data processed by Arduino and transmitted via ESP8266 Wi-Fi to Blynk app; user can remotely monitor and control water sprinkling via solenoid valve</p>	<p>Successful real-time monitoring and control of plant health; optimized plant growth, reduced labor, and conserved water; satisfactory real-time testing on an aloe vera plant; cost-effective and expandable for broader applications like greenhouse and crop monitoring</p>
15	<p>Smart Irrigation and Monitoring System for Pot Plant</p> <p><i>Authors:</i> <i>Gan Yaw Kiat, Mohammad Faiz Liewabdullah</i></p>	<p>Automating plant care and monitoring for busy schedules</p>	<p>Integrated system with Arduino Uno, sensors (soil humidity, ultrasonic, pH), water pump, ESP8266 Wi-Fi; data transmitted to Blynk app; notifications for pH deviations and remote management</p>	<p>Successful real-time monitoring and automated irrigation; simplified gardening tasks and enhanced convenience; system provides timely alerts and remote control</p>

CHAPTER-5

SYSTEM REQUIREMENT SPECIFICATION

5.1 Functional Requirements

The functional requirements of the GreenSense project define the specific operations and functions the system must perform. These requirements ensure that the system delivers the intended functionalities effectively.

1. Real-Time Monitoring:

- The system must continuously monitor and collect data on environmental parameters such as temperature, humidity, soil moisture, pH levels, and light intensity.
- Data should be updated in real-time and made available to the user through the web application.

2. Automated Irrigation Control:

- The system must control the water pump based on soil moisture and temperature data to automate irrigation.
- The system must ensure optimal water usage by adjusting irrigation schedules according to real-time data.

3. Disease Detection:

- The system must capture images of plant leaves using ESP32-CAM and analyze them for disease detection using machine learning algorithms.
- The system should provide alerts and recommendations for disease management.

4. Data Storage and Analysis:

- The system must store collected data in a cloud database for analysis and historical reference.
- The system should analyze data to provide insights and trends on plant health and environmental conditions.

5. User Notifications:

- The system must send notifications to the user when specific thresholds, such as low water levels or detected diseases, are reached.

- Notifications should be sent through the web application and optionally via email or SMS.

6. User Interface:

- The system must provide a user-friendly web application that allows users to monitor plant health, view historical data, receive alerts, and control the system remotely.
- The interface should display real-time data and provide actionable insights.

7. Energy Management:

- The system must manage power efficiently, using rechargeable batteries and solar panels to ensure continuous operation.

5.2 Non-functional Requirements

The non-functional requirements define the overall qualities and attributes of the GreenSense system, ensuring it performs efficiently and meets user expectations.

1. Scalability:

- The system must be scalable to support multiple plants and larger garden setups without compromising performance.
- The architecture should allow for the addition of more sensors and nodes as needed.

2. Reliability:

- The system must operate reliably, with minimal downtime, to ensure continuous monitoring and control.
- The system should have mechanisms to handle sensor malfunctions and data transmission errors.

3. Performance:

- The system must process and analyze data quickly to provide real-time updates and responses.
- The user interface should load data and updates promptly without significant delays.

4. Security:

- The system must ensure data security, protecting user information and

sensor data from unauthorized access.

- Secure communication protocols should be used for data transmission between nodes and the cloud.

5. Usability:

- The web application must be intuitive and easy to use, requiring minimal training for users to operate effectively.

6. Maintainability:

- The system must be easy to maintain, with modular components that can be updated or replaced as needed.
- Documentation should be provided to guide users and developers in troubleshooting and system maintenance.

7. Energy Efficiency:

- The system must be designed to consume minimal power, utilizing energy-efficient components and renewable energy sources like solar panels.

5.3 Hardware Requirements

The hardware requirements outline the essential components needed to build the GreenSense system.

1. ESP32 Microcontrollers:

- Multiple ESP32 microcontrollers for managing sensors and communication.

2. ESP32-CAM Modules:

- ESP32-CAM modules for capturing images of plant leaves for disease detection.

3. Sensors:

- **Temperature and Humidity Sensors** (e.g., DHT22): Measure environmental temperature and humidity levels.
- **Soil Moisture Sensors**: Detect moisture levels in the soil to inform irrigation decisions.
- **Light Intensity Sensors** (e.g., BH1750): Measure the amount of light available to the plant.
- **pH Sensors**: Measure the acidity or alkalinity of the soil.
- **Water Level Sensors** (e.g., Ultrasonic or Float Switch): Monitor water

levels in the storage tank.

4. Water Pumps and Relay Modules:

- Water pumps to automate irrigation, controlled by relay modules connected to ESP32.

5. Power Supply Components:

- Rechargeable batteries and solar panels to provide continuous power to the system.

6. Additional Components:

- Tubing and connectors for water flow.
- Enclosures to protect electronic components from environmental factors.

5.4 Software Requirements

The software requirements define the essential software tools and platforms needed for the development and operation of the GreenSense system.

1. Arduino IDE:

- Development environment for programming ESP32 microcontrollers.

2. Docker:

- Containerization platform for deploying services, including data collection, machine learning, and web applications.

3. Cloud Services:

- **AWS, Azure, or Google Cloud:** Cloud platforms for data storage, processing, and analysis.

4. Machine Learning Framework:

- **TensorFlow or PyTorch:** Frameworks for developing and deploying machine learning models for disease detection.

5. Database:

- **MySQL, PostgreSQL, or MongoDB:** Databases for storing sensor data and user information.

6. Notification Services:

- **Pushbullet, Twilio, or Firebase Cloud Messaging:** Services for sending notifications and alerts to users.

CHAPTER-6

SYSTEM DESIGN

6.1 System Design

6.1.1 System Architecture

The system architecture of the GreenSense project outlines the key components and their interactions to achieve efficient plant monitoring and management. The architecture leverages IoT devices, cloud services, and web applications to provide a comprehensive solution.

Overview:

1. Sensor Nodes:

- **ESP32 Microcontrollers:** Each plant pot is equipped with an ESP32 microcontroller connected to various sensors.
 - **Temperature and Humidity Sensors:** Measure environmental temperature and humidity levels.
 - **Soil Moisture Sensors:** Detect moisture levels in the soil.
 - **Light Intensity Sensors:** Measure the amount of light available to the plant.
 - **pH Sensors:** Measure the acidity or alkalinity of the soil.
 - **ESP32-CAM Modules:** Capture images of plant leaves for disease detection.

2. Wireless Communication:

- **ESP-NOW Protocol:** Facilitates low-power, efficient communication between sensor nodes.
- **Wi-Fi Module:** Central node aggregates data and communicates with the cloud.

3. Central Coordinator Node:

- **ESP32:** Acts as the central data hub, aggregating sensor data and forwarding it to the cloud.

- **Wi-Fi Connection:** Transmits data to cloud services for storage and analysis.

4. Cloud Services:

- **Data Collection Service:** Receives sensor data and stores it in a cloud database.
- **Machine Learning Service:** Analyzes images for disease detection using pre-trained models.
- **Data Processing and Analytics:** Processes and analyzes data to generate insights and trends.

5. Web Application:

- Provides a user-friendly interface for monitoring plant health, viewing real-time data, receiving alerts, and controlling the system remotely.
- Displays data trends and insights to help users make informed decisions about plant care.

6. Automated Irrigation System:

- **Water Pumps and Relay Modules:** Control water flow based on real-time soil moisture and temperature data.
- **Water Storage Tank:** Captures excess water for recycling and future irrigation.

7. Power Management:

- **Rechargeable Batteries and Solar Panels:** Provide continuous power to the system, ensuring sustainability and reliability.

6.1.2 Module Design

The module design of the GreenSense project breaks down the system into individual modules, detailing their functions and interactions. Each module plays a crucial role in achieving the overall system objectives.

1. Sensor Module:

- **Components:** Temperature and humidity sensors, soil moisture sensors, light intensity sensors, pH sensors, ESP32-CAM modules.
- **Function:** Continuously monitor environmental parameters and capture images of plant leaves.

- **Interaction:** Sends data to the ESP32 microcontroller for processing.

2. Data Aggregation Module:

- **Components:** ESP32 microcontrollers, ESP-NOW protocol, Wi-Fi module.
- **Function:** Collects data from sensor nodes and aggregates it at the central coordinator node.
- **Interaction:** Transmits aggregated data to the cloud via Wi-Fi.

3. Cloud Integration Module:

- **Components:** Cloud database, data collection service, machine learning service, data processing and analytics.
- **Function:** Stores, processes, and analyzes sensor data; detects plant diseases using machine learning models.
- **Interaction:** Receives data from the central coordinator node and provides insights to the web application.

4. Web Application Module:

- **Components:** Web development framework (e.g., React, Angular, Vue.js), cloud services API.
- **Function:** Provides a user interface for remote monitoring, data visualization, alerts, and system control.
- **Interaction:** Communicates with cloud services to retrieve data and display it to the user.

5. Irrigation Control Module:

- **Components:** Water pumps, relay modules, water storage tank.
- **Function:** Automates irrigation based on real-time soil moisture and temperature data.
- **Interaction:** Receives control signals from the central coordinator node to manage water flow.

6. Power Management Module:

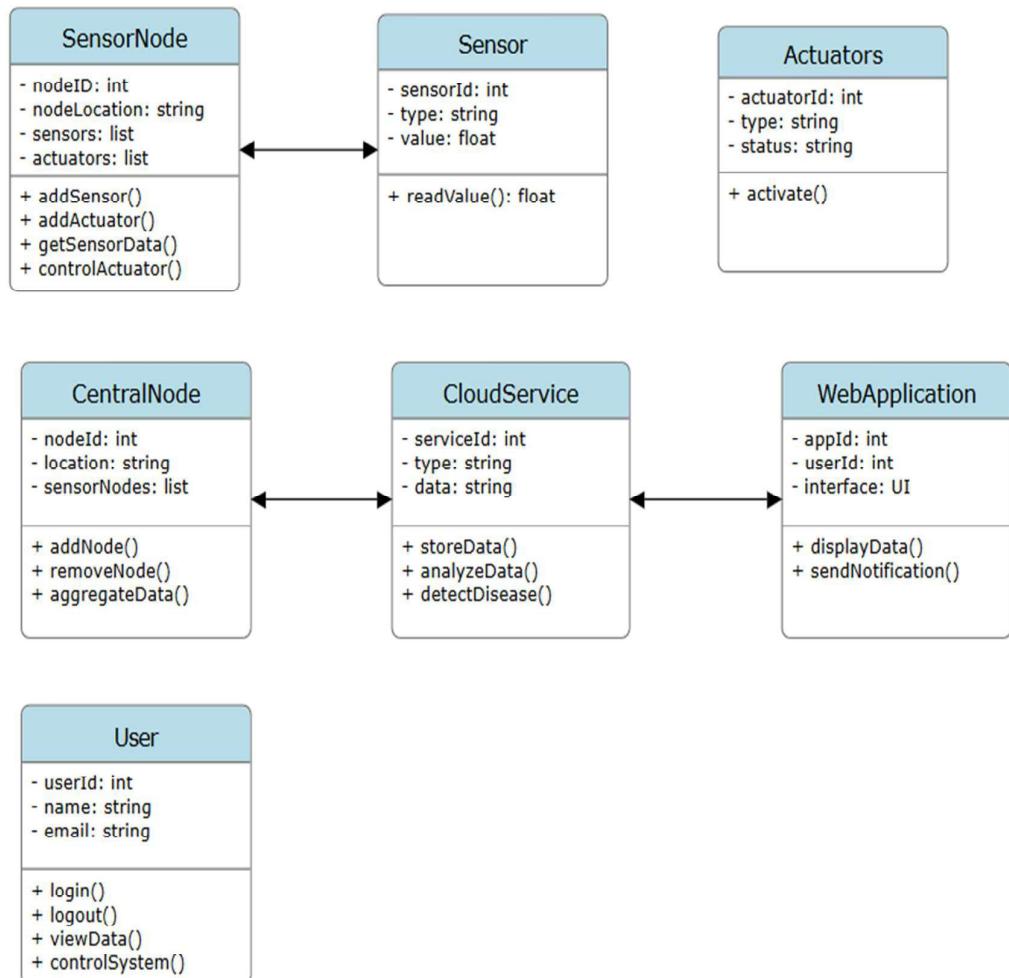
- **Components:** Rechargeable batteries, solar panels.
- **Function:** Provides continuous power to the system, ensuring sustainability and reliability.
- **Interaction:** Powers all system components and ensures efficient energy usage.

By designing and implementing these modules, the GreenSense project aims to deliver a

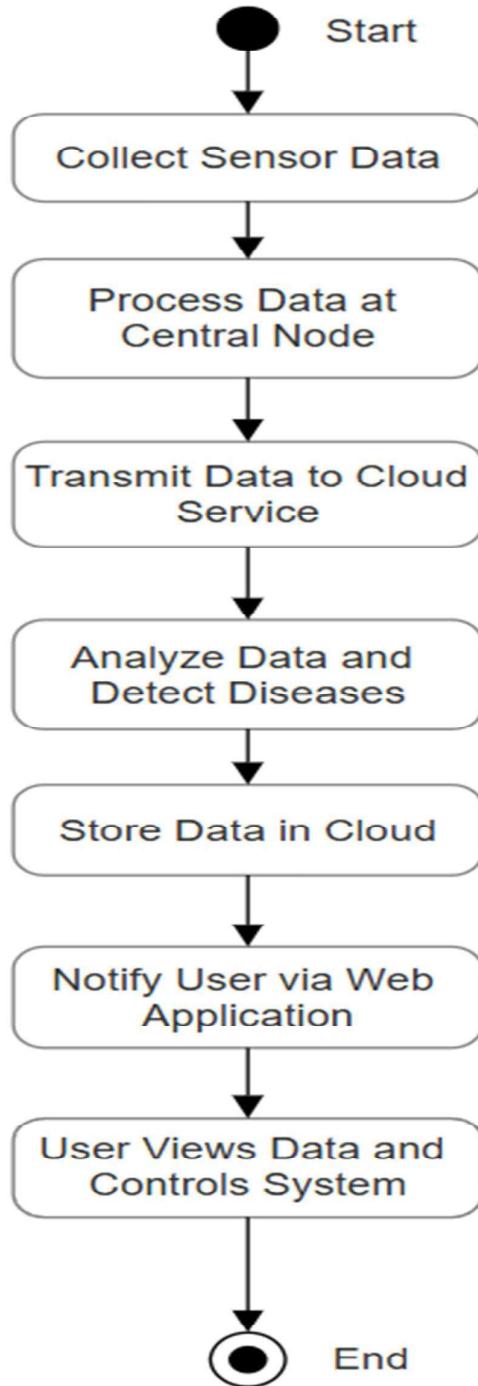
robust, efficient, and scalable solution for smart plant monitoring and management. Each module plays a vital role in achieving the system's objectives, ensuring optimal plant health, resource optimization, and user convenience.

6.2 Detailed Design

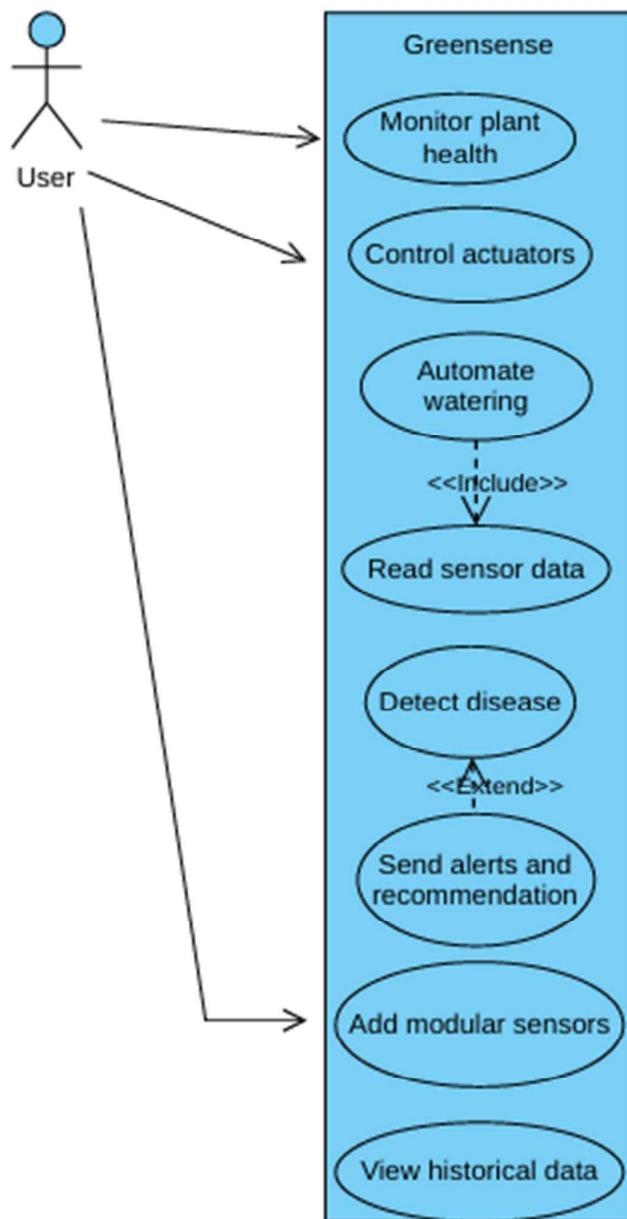
6.2.1 Class Diagram



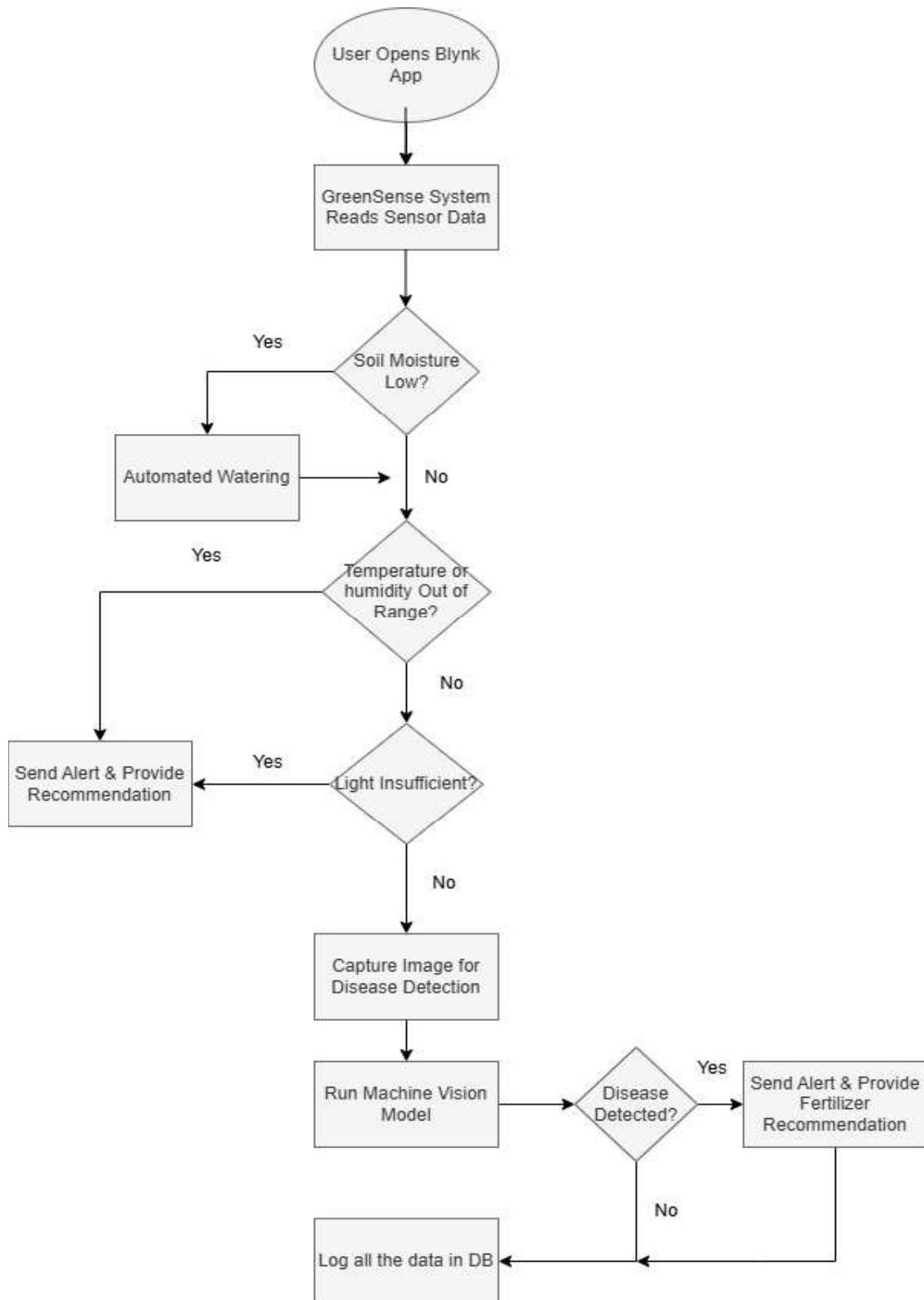
6.2.2 Activity Diagram



6.2.3 Use Case Diagram



6.2.4 Scenarios



CHAPTER-7

APPLICATION

The GreenSense system has several practical applications that can significantly benefit various domains. Here are the key applications:

7.1 Home Gardening

- **Automated Plant Care:** The GreenSense system can be used in home gardens to automate the monitoring and watering of plants. This ensures optimal plant health by providing the necessary water, light, and nutrients at the right time.
- **Remote Monitoring:** Home gardeners can remotely monitor their plants' health using the web application, receiving real-time updates and alerts.
- **Disease Detection:** Early detection of plant diseases through image analysis allows home gardeners to take timely action, reducing plant loss and improving overall garden health.

7.2 Commercial Agriculture

- **Efficient Irrigation:** The system can be deployed in large-scale farming operations to automate irrigation, ensuring efficient water usage and reducing costs associated with manual irrigation.
- **Data-Driven Insights:** Farmers can leverage data analytics to make informed decisions about planting schedules, crop rotation, and soil management, enhancing crop yield and productivity.
- **Pest and Disease Management:** The system's disease detection capability helps in early identification and management of pest and disease outbreaks, minimizing crop damage and loss.

7.3 Greenhouses

- **Climate Control:** GreenSense can be used in greenhouses to monitor and control environmental parameters such as temperature, humidity, and light intensity, creating optimal growing conditions for plants.
- **Automated Systems:** The system automates irrigation, ventilation, and shading

based on real-time data, ensuring consistent and efficient plant growth.

- **Energy Management:** The use of solar panels and energy-efficient components helps in reducing the greenhouse's carbon footprint and operational costs.

7.4 Urban Agriculture

- **Vertical Farming:** In urban settings, GreenSense can be applied to vertical farming setups to monitor and manage plant health, maximizing space utilization and crop yield.
- **Community Gardens:** The system can support community gardens by providing a centralized platform for monitoring and managing multiple plots, fostering collaboration among community members.
- **Rooftop Gardens:** Urban dwellers can use GreenSense to maintain rooftop gardens, ensuring plants receive adequate water and nutrients despite limited space.

7.5 Research and Education

- **Research:** GreenSense can be used in agricultural research to collect and analyze data on various plant species, environmental conditions, and growth patterns, contributing to scientific advancements in agriculture.
- **Educational Institutions:** Schools and universities can integrate GreenSense into their curriculum to teach students about plant biology, environmental science, and the application of IoT and AI in agriculture.

7.6 Smart City Initiatives

- **Urban Green Spaces:** Municipalities can deploy GreenSense in public parks and green spaces to maintain plant health, enhancing the aesthetic and environmental quality of urban areas.
- **Sustainability Goals:** The system supports smart city initiatives by promoting sustainable water usage, reducing resource wastage, and enhancing green cover in urban environments.

CONCLUSION

The GreenSense project presents an innovative and comprehensive solution for smart plant monitoring and management. By leveraging IoT devices, cloud services, and web applications, GreenSense addresses the challenges faced in traditional gardening, commercial agriculture, greenhouses, urban farming, research, and smart city initiatives.

Key Achievements:

- **Real-Time Monitoring:** Continuous monitoring of environmental parameters such as temperature, humidity, soil moisture, pH levels, and light intensity ensures optimal plant health and growth.
- **Automated Irrigation:** The integration of automated irrigation systems based on real-time data significantly reduces water wastage and ensures efficient water usage.
- **Disease Detection:** The use of image analysis and machine learning algorithms for early disease detection allows timely intervention, preventing plant loss and improving overall plant health.
- **User-Friendly Interface:** The web application provides a user-friendly interface for remote monitoring, data visualization, alerts, and system control, making it accessible and convenient for users.
- **Scalability and Flexibility:** The system is designed to be scalable and adaptable, supporting multiple plants, larger garden setups, and various agricultural applications.
- **Sustainability:** The use of renewable energy sources, such as solar panels, and energy-efficient components ensures the system's sustainability and reduces operational costs.

Impact on Various Domains:

- **Home Gardening:** GreenSense simplifies plant care for home gardeners, offering automated monitoring and watering, remote access, and timely alerts.
- **Commercial Agriculture:** Farmers benefit from efficient irrigation, data-driven insights, and pest and disease management, leading to increased productivity and reduced costs.
- **Greenhouses:** The system provides climate control, automated systems, and energy

management, enhancing plant growth and resource efficiency in greenhouses.

- **Urban Agriculture:** GreenSense supports vertical farming, community gardens, and rooftop gardens, maximizing space utilization and promoting sustainable urban agriculture.
- **Research and Education:** The system aids agricultural research and education by providing valuable data and insights into plant biology, environmental science, and the application of IoT and AI in agriculture.
- **Smart City Initiatives:** Municipalities can deploy GreenSense in urban green spaces to maintain plant health, enhancing the aesthetic and environmental quality of urban areas.

Future Enhancements:

- **Advanced Machine Learning Models:** Further development and integration of advanced machine learning models can enhance disease detection accuracy and provide more comprehensive insights.
- **Expanded Sensor Network:** Incorporating additional sensors for monitoring various environmental parameters can improve the system's effectiveness and adaptability.
- **Enhanced User Experience:** Continuous improvements to the web application and user interface can provide a more intuitive and seamless experience for users.
- **Integration with Other IoT Systems:** Integrating GreenSense with other smart home and smart city systems can create a more connected and cohesive ecosystem, enhancing overall efficiency and user convenience.

In conclusion, the GreenSense project demonstrates the potential of IoT and AI technologies in revolutionizing plant monitoring and management. By offering innovative solutions and addressing critical challenges, GreenSense contributes to a greener, more sustainable future for gardening and agriculture.

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