Smart Greenhouses Decision Support System for Tomato Cultivation

24-25J-064

Project Proposal Report

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DECLARATION

I declare that this is my own work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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ABSTRACT

This study aims to develop a decision support system, implemented as a web application, for tomato greenhouses to predict optimal watering schedules and ensure water availability based on real-time environmental conditions. The research addresses critical challenges in irrigation management, particularly the negative effects of over-irrigation and under-irrigation on tomato crop health and yield. It also considers the complexities posed by fluctuating temperatures, which significantly influence the water needs of tomato plants. By integrating IoT sensors to collect real-time data on soil moisture, temperature, humidity, and light, the system leverages machine learning algorithms to analyze this data and generate precise watering schedules. The web application is designed to enhance water efficiency and ensure that the necessary water is available when required. While existing smart irrigation systems provide some benefits, they often fail to accurately predict the specific water requirements needed to maintain optimal conditions. This research seeks to address these gaps, ultimately leading to optimized plant health and improved crop yields in tomato greenhouses. The expected outcome is a robust, scalable system that can be adapted to various greenhouse environments, marking a significant advancement in agricultural technology.

Keywords: Decision Support System, Web Application, Tomato Greenhouses, IoT, Machine Learning, Optimal Watering Schedules, Irrigation Management, Real-Time Data.

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

Efficient water management is a critical aspect of modern agriculture, particularly in greenhouse settings where precise control over environmental conditions is essential for optimizing crop yield and quality. In the domain of smart agriculture, significant research has focused on the development of irrigation systems that leverage Internet of Things (IoT) technologies and machine learning algorithms to enhance water usage efficiency. These systems typically monitor environmental variables such as soil moisture, temperature, humidity, and light intensity, providing data-driven insights to optimize watering schedules. However, while these existing systems have made strides in improving irrigation efficiency, they often fall short in predicting the precise water needs of plants under varying environmental conditions, leading to issues such as over-irrigation or under-irrigation, which can negatively impact crop health and yield.

To undertake this project successfully, a deep understanding of IoT technologies, machine learning algorithms, and their application in agriculture is essential. Familiarity with environmental sensor networks, data analytics, and web application development is also crucial, as the system will require the integration of real-time data collection, processing, and user-friendly interfaces for effective decision-making. Moreover, knowledge of plant physiology, particularly the water needs of tomato plants under different environmental conditions, is vital to ensure the system's recommendations are both accurate and beneficial to crop growth.

Currently, the state of the art in smart irrigation systems is focused on improving water efficiency through automated and semi-automated irrigation methods. Techniques such as precision irrigation, which applies water directly to the root zone of plants, and variable rate irrigation, which adjusts water application rates based on field conditions, are being widely researched and implemented. However, these methods often rely on static irrigation schedules or do not fully account for the dynamic nature of environmental variables, leading to suboptimal water use.

Previous research has attempted to address these issues through various approaches, such as the use of neural networks to predict crop water requirements or the development of closed-loop control systems that adjust irrigation based on real-time feedback. While these methods have shown promise, they often lack the scalability or adaptability required for diverse greenhouse environments.

Our approach seeks to build on this existing work by developing a decision support system that not only predicts optimal watering schedules based on real-time environmental data but also ensures the availability of suitable water for irrigation. By integrating IoT sensors with advanced machine learning models, our system aims to provide more accurate, context-aware recommendations that can be easily adapted to different greenhouse setups, ultimately leading to improved water management and crop yields in tomato cultivation.

2. BACKGROUND & LITERATURE SURVEY

2.1 Background

Tomatoes (Solanum lycopersicum) are highly valued crops that require careful water management to ensure optimal growth and productivity. The balance between too much and too little water is critical, as both extremes can have detrimental effects on tomato plants. Over-irrigation can lead to root diseases, reduced oxygen availability in the soil, and poor nutrient uptake, while under-irrigation can cause water stress, reduce fruit size, and decrease overall yield [1] [2].

Deficit irrigation (under irrigation) significantly decreased the vegetative growth, flowering, fruit yield parameters, photosynthetic pigments (chl. a, b and carotenoids), leaves mineral content (N, P, K and Fe %), leaf relative water content (LRWC) and membrane stability index (MSI) of tomato plants, compared to control treatment (100% ETo). While, water stress treatments improved leaves proline content, irrigation water use efficiency (IWUE) and some fruit quality characteristics for tomatoes [3]. high irrigation frequency favored the vegetative growth, stomatal conductance, CO2 assimilation and transpiration and fruit yield [4].

The climate in the world is getting warmer for various human activities and increasing levels of CO2 which results in the greenhouse's emergence effect. Greenhouse gases are an important factor in instability during the changing seasons because of excessive energy use. Various levels of microclimate influence various plants in a smart greenhouse. To protect plants, the microclimate must be arranged in such a way as to be suitable and optimal for plant growth [5].

Temperature regulation is another key factor in greenhouse management. Tomatoes thrive in a specific temperature range, typically between 21°C and 27°C (70°F and 82°F) [6]
For the greenhouse cultivation of tomato a temperature of 26 °C is better than 32 °C and, for both these temperatures, high frequency irrigation (in this case, FR1) is optimal. However, at 32 °C the irrigation management is less influential than at 26 °C [7]. Deviations from this range can impact water uptake and plant metabolism. High temperatures can increase the plants' water requirements, leading to higher irrigation needs, while low temperatures can reduce the efficiency of water absorption and nutrient uptake. Thus, maintaining stable environmental conditions is crucial for effective water management [8].

Greenhouse environments offer controlled conditions that can be manipulated to optimize crop production. However, maintaining these conditions requires precise monitoring and management. Traditional irrigation systems often fall short in adapting to real-time changes in environmental conditions, leading to inefficiencies. As such, there is a growing need for advanced systems that integrate real-time data to make informed irrigation decisions [9].

Traditional methods of controlling the greenhouse environment are often manual, leading to suboptimal conditions and reduced plant yields. However, advancements in the Internet of Things (IoT) have enabled automated monitoring and control systems. IoT-based smart greenhouses can maintain optimal growing conditions by adjusting temperature, humidity, and other factors in real time. For example, mist cooling systems integrated with IoT technology can regulate extreme temperatures and humidity levels, creating an ideal environment for tomato cultivation [10] [11].

The implementation of IoT in agriculture is revolutionizing crop management, allowing for precise control of the microclimate, predicting harvest times, and improving overall efficiency. Smart greenhouses, equipped with IoT sensors and automation systems, protect plants from adverse conditions and ensure optimal growth environments, making them a critical development in modern agriculture [10] [11].

2.2 Literature Survey

Recent advancements in smart irrigation technologies have significantly improved the management of water resources in agriculture. Smart irrigation systems use IoT sensors to continuously monitor various environmental parameters, including soil moisture, temperature, humidity, and light intensity. This data is then used to automate irrigation processes, ensuring that plants receive the appropriate amount of water based on their immediate needs [7][8].

For instance, IoT-based systems have been shown to enhance irrigation efficiency by automating water delivery based on real-time data. Research indicates that such systems can reduce water usage by up to 30% while maintaining or even improving crop yields. These systems typically involve the deployment of soil moisture sensors that provide feedback on soil conditions, which is then processed to adjust watering schedules [9][10].

Machine learning algorithms have emerged as a powerful tool in refining irrigation practices. By analyzing historical and real-time data, these algorithms can predict the optimal watering requirements for crops under varying environmental conditions. A study by Liu et al. (2019) demonstrated that machine learning models could significantly improve the accuracy of irrigation scheduling by learning from data patterns, leading to more efficient water use [11][12].

However, despite these advancements, there is no existing system that accurately predicts the specific watering schedules and the precise amount of water required for plants based on varying environmental conditions on a daily, weekly, or monthly basis. While many smart irrigation systems focus primarily on soil moisture levels, they often overlook the integration of other crucial environmental factors like temperature, humidity, and light. This limitation prevents these systems from providing a comprehensive solution that adapts to the dynamic needs of plants [13][14].

The current gap in smart irrigation technologies highlights the need for a more advanced system that not only monitors real-time environmental data but also predicts the exact watering schedules and quantities required for optimal plant health. Addressing this gap could lead to significant improvements in water efficiency, plant health, and crop yield, particularly in controlled environments like greenhouses [15][16].

3. RESEARCH GAP

In the context of precision agriculture, especially within the controlled environment of tomato greenhouses, existing IoT-based solutions present significant limitations that hinder optimal crop management. A close examination of current systems reveals several critical gaps that need to be addressed to enhance the effectiveness and efficiency of irrigation practices.

The Research A ‘IoT-Based Precision Irrigation System’ effectively automates water irrigation and monitors soil moisture, light, and temperature, but it lacks the capability to control temperature directly within the greenhouse environment. Furthermore, while it checks water levels and availability, it does not provide predictions for watering schedules or the precise quantity of water needed based on varying environmental conditions. This gap limits the system's ability to prevent over-irrigation or under-irrigation, which can negatively impact crop yields [12].

Similarly, the Research B ‘Smart High-Yield Tomato Cultivation System’ offers automated water irrigation but falls short in its monitoring capabilities, particularly in temperature control. This system also lacks the predictive analytics necessary to optimize watering schedules and quantities, relying instead on reactive measures that do not account for upcoming environmental changes [13].

The Research C ‘Indoor seed germination system’ demonstrates a significant gap by not incorporating automated water irrigation, multi-factor environmental monitoring, or predictive capabilities. This system's limited scope means it cannot adequately address the complex needs of tomato cultivation in greenhouses, where precise control over environmental factors is crucial [14].

The Research D ‘LoRaWAN-based IoT system’, although offering strong monitoring capabilities and real-time alerts through its dashboard, does not support temperature control or predictive watering schedules. The absence of these features restricts its effectiveness in maintaining optimal growing conditions, particularly during periods of extreme temperature fluctuations [15].

To visually represent these gaps, the research gap chart shown in **Figure 1** (to be inserted below) provides a clear comparison of the features offered by existing products/research against the proposed system

Existing Products / Research	**Features**					
	Automated Water irrigation	**Soil Moisture, Light & Temperature Monitoring**	**Temperature Control**	**Water level & Availability checking**	**Predict Watering Time, Schedule, Quantity**	**Real-Time Alerts (Dashboard)**
Research A	✓	✓	✗	✓	✗	✗
Research B	✓	✗	✗	✓	✗	✓
Research C	✗	✓	✗	✗	✗	✗
Research D	✗	✓	✗	✗	✗	✓
Proposed System	✓	✓	✓	✓	✓	✓

Figure 1 Comparison between existing systems

3.1 Proposed System

The proposed decision support system is designed to comprehensively address these gaps by integrating a wide range of features specifically tailored for optimal tomato greenhouse management. Unlike existing systems, the proposed solution not only automates water irrigation but also incorporates comprehensive environmental monitoring of soil moisture, light, and temperature. The system includes real-time environmental control features, such as activating exhaust fans when temperatures exceed the optimal range (21-27°C or 70-82°F) and turning on heaters when temperatures drop below this range. Additionally, when soil moisture levels are too low, the water pump is automatically activated to ensure the plants receive adequate hydration.

A key innovation of the proposed system is its advanced predictive capabilities. By leveraging machine learning algorithms, the system analyzes real-time and historical data to generate precise watering schedules and determine the exact quantity of water needed not only for the present day but also for future periods. Users can predict water needs for the upcoming day, week, or even the entire crop cycle, enabling them to plan and manage resources more effectively. This adaptability, which accounts for varying environmental conditions, sets the proposed system apart from existing solutions, offering a more precise and sustainable approach to irrigation.

Moreover, the proposed system's user interface (UI) dashboard is equipped with both automated and manual control features. Users have the flexibility to manually operate essential functions, such as turning on the water pump or activating exhaust fans, directly from the web application. This added layer of control ensures that users can make immediate adjustments when necessary, providing both flexibility and reliability in managing the greenhouse environment.

In summary, the proposed decision support system bridges the gaps identified in current smart irrigation technologies by offering a comprehensive, data-driven approach to greenhouse management. Its novel features, including predictive analytics for future watering needs, automated and manual environmental control, and comprehensive monitoring, provide a robust solution that enhances crop yield, reduces resource waste, and ensures the sustainability of greenhouse operations.

4. RESEARCH PROBLEM

In modern agriculture, particularly in greenhouse environments like those used for tomato cultivation, effective water management is critical for ensuring optimal plant growth and maximizing crop yields. However, traditional irrigation practices and even existing smart irrigation systems often fall short in addressing several key challenges. These challenges include the inability to accurately predict watering schedules based on real-time environmental conditions, the lack of comprehensive control over greenhouse temperature and humidity, and the absence of systems that can determine the exact amount of water needed over various time frames.

How can we develop a decision support system that accurately predicts optimal watering schedules and ensures the availability of water, tailored specifically to real-time environmental conditions within a tomato greenhouse?

This research problem focuses on bridging the gap between current smart irrigation solutions and the specific needs of greenhouse tomato cultivation. The study aims to explore the limitations of existing systems in predicting not only when to water plants but also how much water is needed based on fluctuating conditions such as temperature, humidity, and soil moisture levels. Additionally, the research will address the issue of ensuring water availability and maintaining proper environmental conditions through automated controls and predictive models.

The core issue lies in the fact that current solutions do not offer the predictive accuracy and environmental control necessary for optimizing irrigation in tomato greenhouses. Without these capabilities, farmers risk both over-irrigation, which wastes resources and can damage plants, and under-irrigation, which can lead to reduced yields and poor plant health. Therefore, this research will focus on developing a comprehensive decision support system that integrates IoT technology and machine learning to address these gaps, offering a more precise, reliable, and sustainable approach to managing tomato greenhouse environments.

5. OBJECTIVES

The objectives of this study are aimed at addressing the key challenges in irrigation management for tomato greenhouses through the development of a decision support system that leverages IoT and machine learning technologies. The objectives inform the reader of the specific goals this study seeks to achieve and how it intends to contribute to the field of precision agriculture.

5.1 Main Objective

The main objective of this study is to develop a comprehensive web-based decision support system that accurately predicts optimal watering schedules and ensures water availability in tomato greenhouses based on real-time environmental data. This system aims to enhance irrigation management by integrating IoT sensors and machine learning models to monitor and control environmental factors such as soil moisture, temperature, humidity, and light levels, ultimately improving crop health and maximizing yield.

5.2 Specific Objectives

1. To collect and analyze real-time environmental data using IoT sensors.

- This objective focuses on the deployment of IoT sensors within the greenhouse environment to monitor key variables such as soil moisture, temperature, humidity, and light intensity. The collected data will form the foundation for the decision-making processes of the system.

2. To develop machine learning models that predict optimal watering schedules and determine the precise amount of water required based on collected environmental data.

- This objective involves developing machine learning models that analyze real-time environmental data, such as soil moisture, temperature, humidity, and light levels, to predict optimal watering schedules and determine the precise amount of water needed. These models will adapt to changing conditions, ensuring the watering schedule and water usage are always optimal.

3. To ensure continuous water availability.

- This objective involves implement an ultrasonic sensor in the water tank to continuously monitor water levels, providing live readings to the system. The system will alert the user through the web application UI if water levels drop too low, allowing them to take necessary action to prevent irrigation disruptions.

3. To train the machine learning model using real datasets.

- This objective involves collecting real datasets from agricultural-related department authorities and surveys. These datasets will be cleaned and used to train the machine learning model, enhancing its accuracy and reliability in predicting watering schedules and water requirements.

4. To implement automated control mechanisms for temperature and water supply in the greenhouse.

- This objective seeks to automate the activation of cooling fans, heaters, and water pumps based on real-time data and the predictions made by the system, ensuring that optimal conditions are maintained for tomato growth always.

5. To design a user-friendly web application interface that allows manual control and monitoring of the greenhouse environment.

- Beyond automation, the system will provide users with a dashboard interface to manually control irrigation, temperature regulation, and other environmental factors, ensuring flexibility in managing the greenhouse.

6. To evaluate the system's effectiveness in improving tomato crop yield and water use efficiency.

- This final objective will assess the performance of the proposed system in a real-world greenhouse setting, measuring its impact on both crop yield and water consumption, and comparing it to existing irrigation practices.

6. METHOTOLOGY

6.1 System Architecture Diagram

The proposed system is designed to create a Smart Greenhouse Decision Support System specifically tailored for tomato cultivation. The system leverages IoT devices to gather real-time environmental data, which is then used to train a machine learning model to predict optimal watering schedules and control various greenhouse actuators, such as water pumps, heaters, and cooling fans. The system architecture is detailed in the accompanying diagram, which illustrates the flow of data and interactions between components.

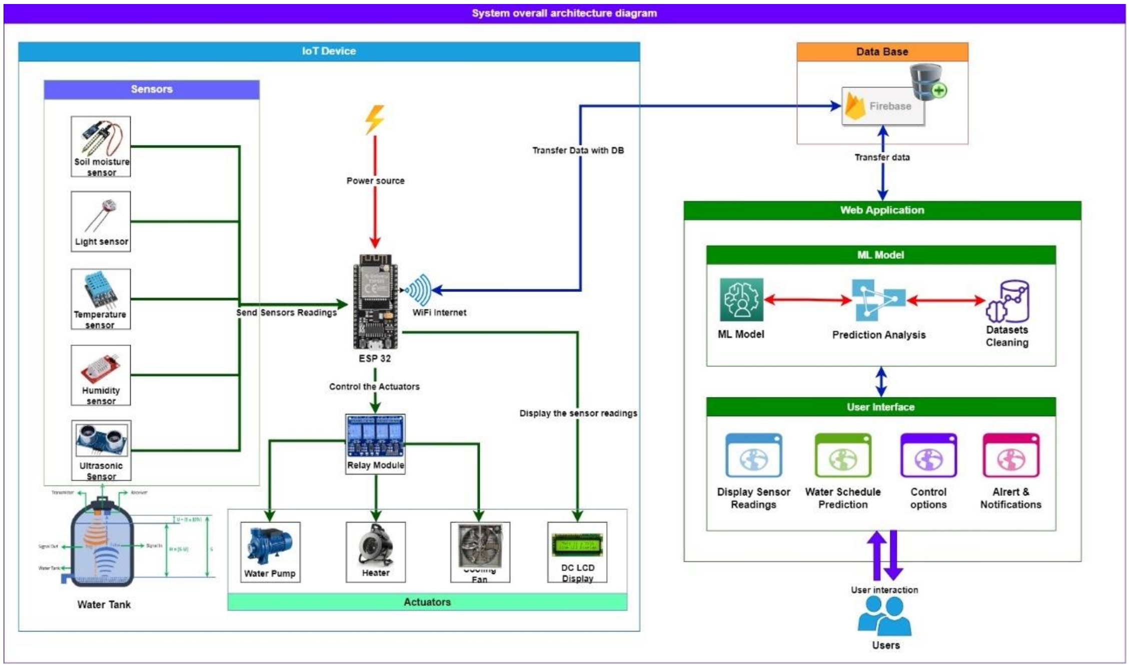

Figure 2 High-level System Architecture Diagram

In this project, the system diagram is a crucial element that outlines the overall architecture of the Smart Greenhouse Decision Support System for Tomato Cultivation. This system is designed to integrate a range of IoT sensors, a central microcontroller (ESP32), a Firebase database for real-time data storage, and a machine learning model for predictive analytics. The primary objective of this system is to enhance the efficiency of water use in tomato cultivation by optimizing irrigation schedules based on real-time environmental data.

The system starts with a variety of sensors(soil moisture, temperature, humidity, light, and ultrasonic sensors) each strategically placed within the greenhouse to monitor key environmental parameters. These sensors feed data into the ESP32 microcontroller, which acts as the system's brain, processing the inputs and making decisions about when and how much to water the plants. The ESP32 is connected to a relay module that controls actuators, such as the water pump, heater, and cooling fans, allowing for automatic adjustments in the greenhouse environment.

Data collected by the sensors is transmitted wirelessly to a Firebase database via Wi-Fi. Firebase is used here due to its real-time capabilities and scalability, ensuring that the data is stored and accessible for further analysis. The stored data is then fed into a machine learning model, which has been trained to predict optimal watering schedules based on historical and real-time environmental conditions. The system's predictions are displayed on a user-friendly web interface, where users can monitor sensor readings, receive alerts, and even manually control the actuators if necessary. This integration of IoT, machine learning, and cloud storage is key to achieving the project's main objective: optimizing water use to improve tomato crop yields.

6.1.1 Algorithmic Models

1. **Machine Learning Models**

   Regression algorithms, such as Linear Regression or Random Forest Regression, are used to predict continuous variables, like the quantity of water needed for irrigation. These models take environmental factors (e.g., soil moisture, temperature, humidity) as inputs to provide precise watering schedules.

2. **Decision Support Systems**

   Rule-based systems use predefined rules to make decisions. For example, if the soil moisture drops below a certain threshold, the system automatically turns on the irrigation. This approach ensures that greenhouse conditions are maintained within optimal ranges without manual intervention.

3. **Time Series Analysis**

   The ARIMA (AutoRegressive Integrated Moving Average) algorithm is used for forecasting based on time series data. It can predict future temperature, humidity, and other environmental conditions, which helps in adjusting the greenhouse's control systems proactively.

4. **Control Systems**

   PID (Proportional-Integral-Derivative) control is a feedback mechanism widely used in control systems. It continuously adjusts the system's actions (e.g., heating, cooling) to maintain desired conditions by minimizing the difference between actual and target values (e.g., temperature).

These alogorithm methodologies are integral to creating a sophisticated and responsive Smart Greenhouse system that efficiently manages resources, optimizes plant growth conditions, and adapts to changing environmental factors.

6.2 Project Execution Plan

The project will be carried out through a structured approach that includes the following phases:

1. System Design and Development:

- Develop the overall system architecture, ensuring all hardware and software components are integrated seamlessly.
- Implement the IoT device, ensuring that sensors are correctly calibrated and connected to the ESP32 microcontroller.
- Set up the Firebase database for data storage and real-time access.

2. Data Collection and Preprocessing:

- Collect real-time environmental data from the greenhouse using the IoT sensors.
- Acquire historical data from agricultural department authorities, focusing on irrigation practices and environmental conditions specific to tomato cultivation.
- Conduct surveys with local farmers and agricultural experts to gather qualitative data on best practices and challenges in tomato cultivation.
- Preprocess the data, including cleaning, normalization, and feature selection, to ensure it is suitable for training the machine learning model.

3. Machine Learning Model Development:

- Develop and train a machine learning model using the processed datasets.
- Integrate the model with the web application, ensuring it can make real-time predictions and control the actuators based on environmental data.

4. System Integration and Testing:

- Integrate all components, including the IoT device, Firebase database, machine learning model, and web application.
- Conduct rigorous testing to ensure that the system functions correctly, sensor readings are accurate, and predictions from the machine learning model are reliable.

5. User Interface and Experience Development:

- Design a user-friendly web interface that allows users to monitor sensor data, view watering schedule predictions, and manually control greenhouse actuators.
- Implement features to provide real-time alerts and notifications based on system predictions.

6. Evaluation and Feedback:

- Evaluate the system's effectiveness in improving tomato crop yield and water use efficiency.
- Collect feedback from users (farmers and agricultural experts) to make necessary adjustments to the system.

6.3 Software Solution

The development of the Smart Greenhouse Decision Support System (SGDSS) for Tomato Cultivation is grounded in the principles of the Software Development Life Cycle (SDLC). This structured process ensures that all aspects of the software development are systematically approached, from initial concept to final deployment, maintaining code accuracy and consistency throughout the project.

Given the dynamic nature of agricultural environments and the need for real-time data processing, an Agile methodology was selected for the development of this system. Agile, particularly the Scrum framework, offers the flexibility required to adapt to changing requirements and feedback from end-users, such as farmers and agricultural experts. This adaptability is crucial in a project where environmental conditions can change rapidly, and user needs must be met efficiently.

The Scrum framework divides the project into iterative cycles known as sprints. Each sprint is typically two to four weeks long and focuses on delivering a specific piece of functionality, such as the IoT sensor integration or the machine learning model's training and deployment. This approach allows the development team to focus on incremental improvements and respond quickly to any issues or new requirements that arise.

Figure 3 Agile Methodology

6.3.1 Requirements Gathering

The first step in Agile development involves gathering all the necessary requirements for the project. This includes identifying the key functionalities, user needs, and technical specifications for the Smart Greenhouse system. A product backlog will be created, listing all the tasks and features that need to be developed. These tasks will be prioritized based on their importance and the value they bring to the project.

Key Activities:

- Conduct stakeholder meetings to gather requirements.
- Identify the core features like IoT sensor integration, machine learning model development, and web interface design.
- Create a product backlog and prioritize tasks.

6.3.2 Sprint Planning

Once the backlog is created, the team will plan the first sprint. In Sprint Planning, the team selects the highest-priority tasks from the backlog to work on during the sprint.

The goal is to deliver a working increment of the project by the end of the sprint, typically lasting 2-4 weeks.

Key Activities:

- Select backlog items for the sprint.
- Define sprint goals and tasks.
- Assign tasks to team members based on their expertise and workload.

6.3.2 Design and Prototyping

In the initial sprints, the team will focus on designing the system architecture and creating prototypes. This includes developing the overall system design, setting up the IoT infrastructure, and creating mockups for the web interface.

Key Activities:

- Develop system architecture diagrams and wireframes.
- Design the layout for the user interface.
- Prototype the IoT device with basic functionality for data collection.

6.3.3 Development

During the development phase, the team will work on coding the core components of the system. This includes programming the IoT sensors, integrating them with the ESP32 microcontroller, developing the machine learning model, and building the web application. Each sprint will focus on completing specific features and functionalities.

Key Activities:

- Implement IoT sensor data collection and storage in Firebase.
- Develop and train the machine learning model using the collected data.
- Build the web interface to display sensor data and machine learning predictions.

6.3.4 Testing and Quality Assurance

After development, the system will undergo rigorous testing to ensure that all components function as expected. Testing will be done in parallel with development, with each sprint including unit tests, integration tests, system test and user acceptance tests. The goal is to identify and fix any issues early in the development process.

Key Activities:

- Perform Unit tests, Integration tests, System test and User acceptance tests
- Perform unit testing on individual components.
- Perform integration testing to ensure product interoperability.
- Collect user feedback and perform user acceptance testing.

6.3.5 Release and Deployment

Once the system has been thoroughly tested, it will be deployed in a real-world greenhouse environment. This phase involves setting up the IoT devices, configuring the web application, and ensuring that the system operates as expected in a live setting. Continuous monitoring will be in place to address any issues that may arise during deployment.

Key Activities:

- Deploy the IoT devices and connect them to the greenhouse environment.
- Set up the web application for real-time monitoring and control.
- Ensure the system is operational and meets the user’s needs.

6.3.6 Review and Retrospective

At the end of each sprint, the team will hold a Sprint Review and Retrospective meeting. The Sprint Review will focus on what was accomplished during the sprint, and the Retrospective will identify what went well and what can be improved in future sprints. This iterative feedback loop ensures continuous improvement throughout the project.

Key Activities:

- Review completed tasks and features.
- Gather feedback from stakeholders.
- Identify areas for improvement and prepare for the next sprint.

6.3.7 Continuous Improvement and Monitoring

Even after deployment, the Agile process continues with regular monitoring and updates. The team will gather data on system performance, user satisfaction, and the impact on tomato crop yield. Based on this data, further improvements will be made to optimize the system's effectiveness.

Key Activities:

- Monitor system performance in real-time.
- Gather user feedback for further enhancements.
- Plan and execute future sprints for continuous improvement.

This iterative process is illustrated in Figure - 3, which depicts the Agile development cycle used for this project. The cyclical nature of Agile allows for continuous improvement and adaptation, ensuring that the SGDSS remains aligned with user needs and environmental demands.

By adopting Agile, the project team can manage the inherent uncertainties in agriculture-related projects more effectively, delivering a solution that is not only robust and reliable but also adaptable to future advancements in IoT and machine learning technologies.

6.3.8 Data Collection and Preparation Methodology

The success of the machine learning model depends heavily on the quality and relevance of the datasets used for training. The primary data for this project will be collected from these main sources:

- Department of Agrarian Development Authorities - We will acquire datasets related to tomato cultivation, including information on irrigation practices, environmental conditions, and crop yields.
- Surveys - Conduct surveys with local farmers and agricultural experts to gather additional data on best practices and challenges faced in tomato cultivation.
- Real-time Sensor Data - Collected directly from the IoT sensors installed in the greenhouse.

All collected data will undergo thorough preprocessing, including cleaning, normalization, and feature selection, to ensure it is suitable for training the machine learning model. The model will be trained on this data to predict optimal watering schedules and control greenhouse actuators effectively.

6.4 Conclusion of the Project

The anticipated conclusion of this project is the successful development and deployment of the Smart Greenhouse Decision Support System, which will significantly enhance water use efficiency in tomato cultivation. The system is expected to provide accurate predictions for optimal watering schedules, ensure water availability, reducing water waste and improving crop yields. By automating key greenhouse operations, the system will also reduce the need for manual labor, allowing farmers to focus on other critical aspects of crop management. The user-friendly web interface will make it easy for farmers to monitor greenhouse conditions, receive alerts, and control actuators, leading to better decision-making and improved productivity. This project has the potential to be scaled and adapted to other crops and greenhouse environments, making it a valuable tool in modern agricultural practices.

7. PROJECT REQUIREMENTS

7.1 Functional Requirements

Functional requirements outline the specific functionalities that the system must have to meet the project's objectives. For the Smart Greenhouse Decision Support System, these include:

1. Real-time Data Collection - The system must collect real-time data on soil moisture, temperature, humidity, light, and water turbidity using IoT sensors.
2. Automated Control - The system should automatically control greenhouse actuators, such as turning on water pumps when soil moisture is low or activating cooling fans when the temperature is high.
3. Machine Learning Predictions - The system should predict optimal watering schedules based on historical and real-time environmental data using a machine learning model.
4. Data Storage and Retrieval - The system must store sensor data in a Firebase database and allow real-time data retrieval for analysis and decision-making.
5. User Interaction - The system must provide a user-friendly web interface that allows users to monitor environmental conditions, view predicted watering schedules, and manually control greenhouse components.
6. Alert System - The system should send alerts or notifications based on critical environmental thresholds or predictions.

7.2 User Requirements

User requirements focus on the needs and expectations of the end users of the system. For this project, the users include greenhouse operators, farmers, and agricultural experts. Key user requirements include:

1. Ease of Use - The interface should be intuitive, with simple navigation and clear instructions, allowing users to interact with the system without needing advanced technical skills.
2. Customizability - Users should be able to customize the system based on their specific greenhouse setup, such as adjusting threshold values for sensors or modifying watering schedules.
3. Accessibility - The system should be accessible from any device with an internet connection, allowing users to monitor and control the greenhouse remotely.
4. Real-time Feedback - Users need real-time feedback on the status of the greenhouse environment, including sensor readings and system actions.
5. Security - User data and system operations should be secure, with authentication mechanisms to protect against unauthorized access.

7.3 System Requirements

System requirements define the hardware and software components necessary to implement the project. They include,

7.3.1 Hardware Requirements

1. **1.** Microcontroller - ESP32 to process data and control actuators.
2. **2.** Display – DC LCD Display for local data visualization.

3. Power Supply - To ensure continuous operation of the microcontroller and sensors.
4. Relay Modules - To interface the microcontroller with high-power devices like pumps and fans.
5. Jumper Wires & Breadboard - For prototyping connections between components.
6. Sensors
   - Soil Moisture Sensors - for monitoring soil water levels.
   - Temperature Sensors - to track the greenhouse's internal temperature.
   - Humidity Sensors - for measuring air moisture content.
   - Light Sensors - to monitor light intensity.
   - Ultrasonic Sensor - for water tank's water level measurements.

7.3.2 Software Requirements

1. Python -for backend development and machine learning model implementation.
2. Flask - for web server framework to build the web application.
3. Arduino IDE - for programming the ESP32 microcontroller.
4. IntelliJ IDEA - for software development.
5. Firebase - for cloud-based database management.
6. Web Technologies - including HTML, CSS, and JavaScript for the UIs.

7.4 Personnel Requirements

To enhance the quality, knowledge, continuation and integrity of the research the following are the required personnel.

- Department of Agrarian Development in Sri Lanka
- Mr. Krishantha Jayawardhana, Agrarian Services Center, Monaragala.
- Department of Agriculture Sri Lanka

7.5 Non-functional Requirements

Non-functional requirements address the quality attributes of the system, such as performance, security, and usability.

1. Performance - The system must process and respond to sensor data in real-time, with minimal latency in executing automated controls.
2. Reliability - The system must operate consistently with high uptime, ensuring critical environmental conditions are always monitored.
3. Scalability - The system should be scalable to accommodate additional sensors or functionalities in the future.
4. Security - The system must incorporate security measures to protect user data and ensure the integrity of system operations.
5. Maintainability - The system should be easy to update and maintain, with clear documentation for both software and hardware components.

These requirements provide a comprehensive foundation for the successful design, development, and deployment of the Smart Greenhouse Decision Support System, ensuring that it meets both user needs and technical specifications.

7.6 Use Case Diagram

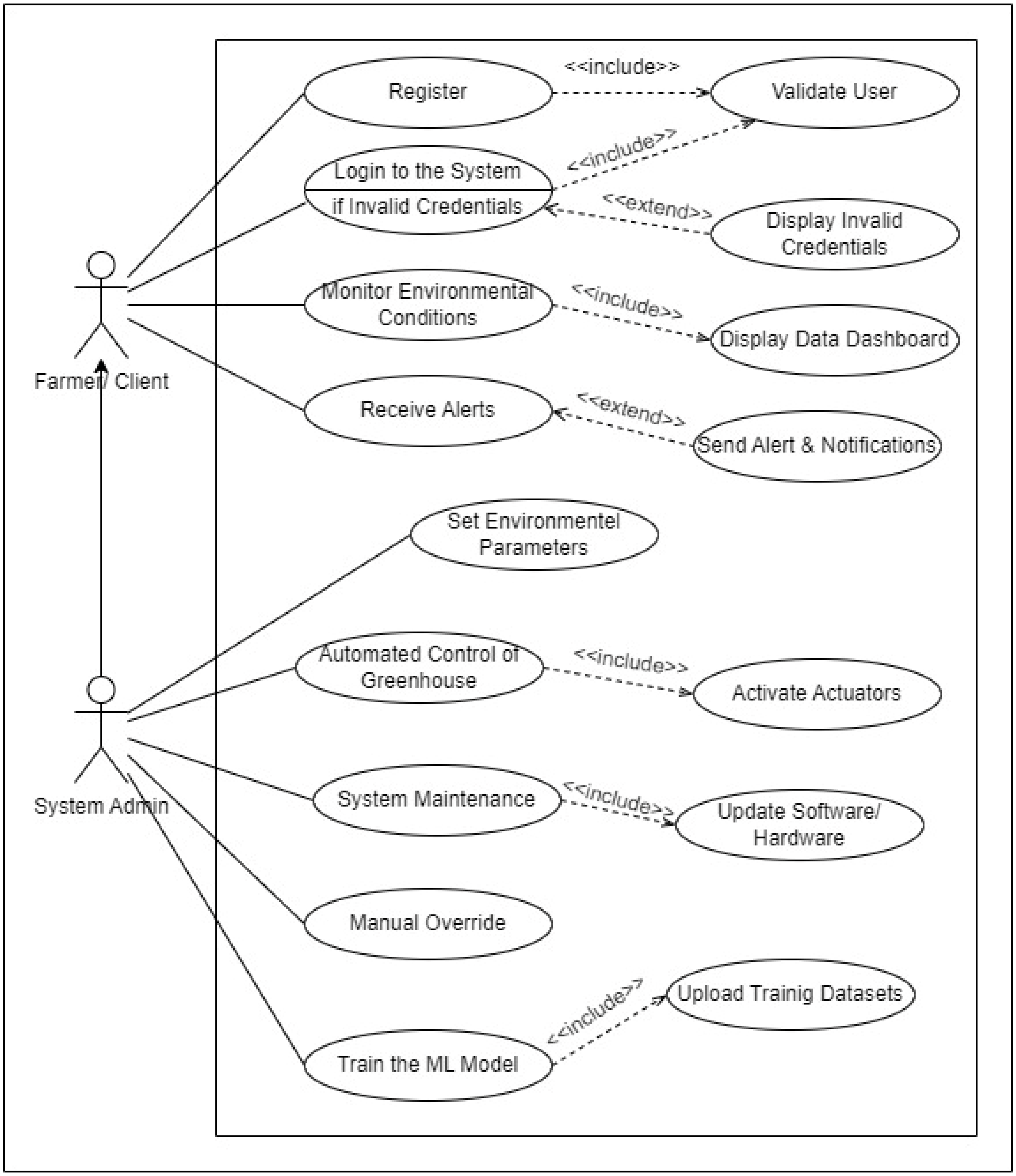

Figure 4 System Overall Use Case Diagram

7.7 Wireframes

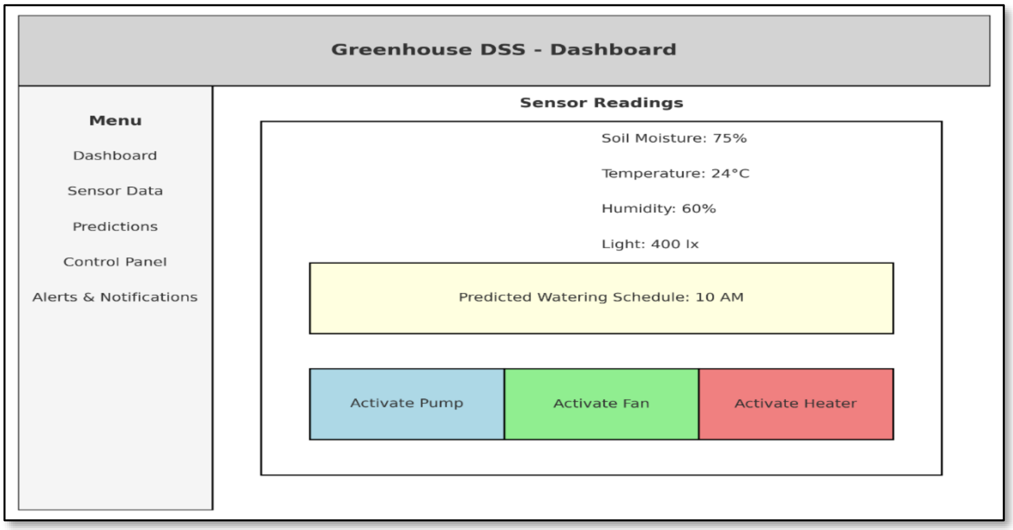

Figure 5 Wireframes for User Interface

8. PROJECT TIMELINE AND TASK ASSIGNMENT

8.1 Gantt Chart

Figure 6 Gantt Chart

8.2 Work breakdown Chart

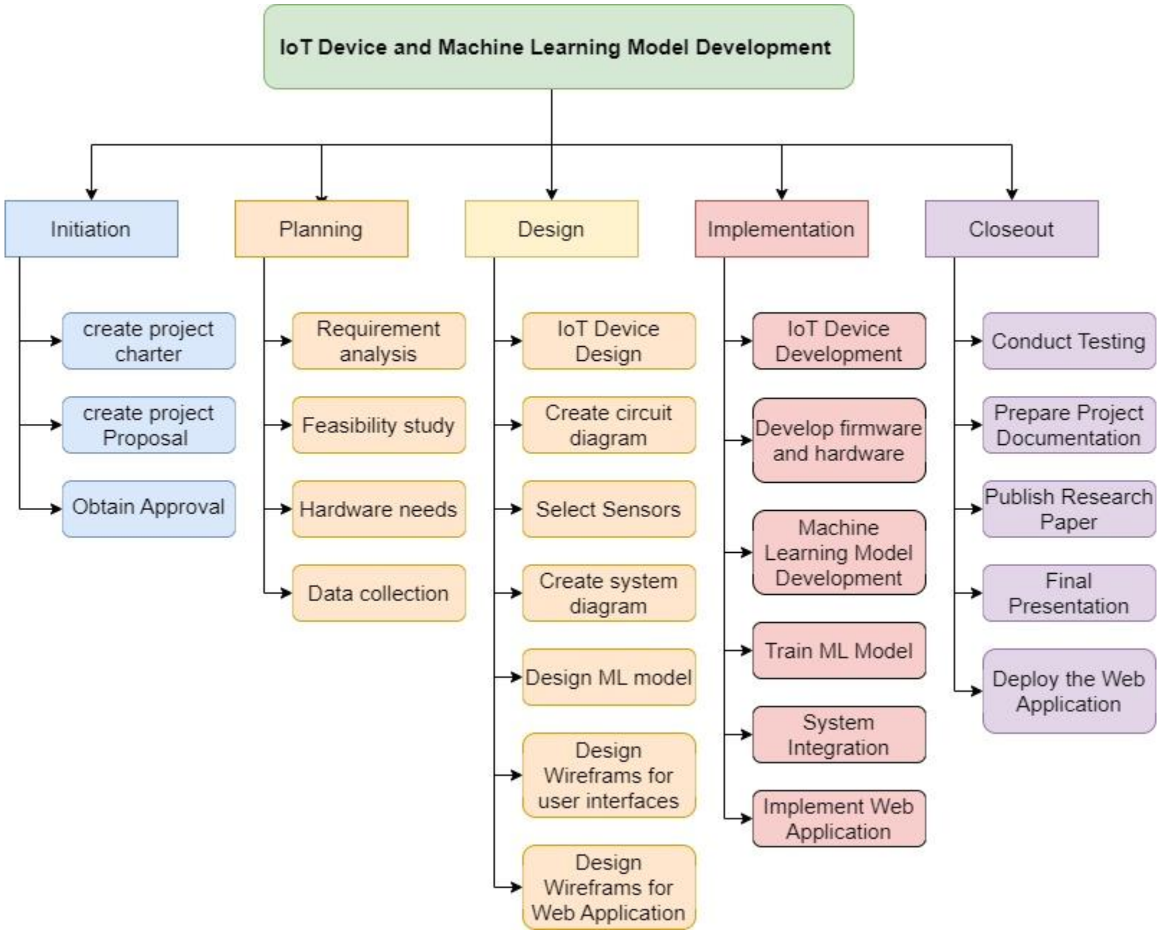

Figure 7 Work breakdown structure

9. COMMERCIALIZATION OF THE PRODUCT

9.1 Market Opportunity

Our Smart Greenhouse Decision Support System is designed to revolutionize tomato cultivation by optimizing watering schedules and improving resource efficiency. With a growing focus on sustainable agriculture, this system targets greenhouse operators and agricultural businesses seeking advanced solutions for better crop management.

Our system provides:

- Efficient Resource Management:
  - ➢ Reduces water waste and maximizes crop yields through precise, data-driven irrigation.

- Intuitive Interface:
  - ➢ A user-friendly web application for easy monitoring and control of greenhouse conditions.

9.2 Commercial Strategy

1. Development and Testing:

   - We will refine the system through real-world testing and user feedback to ensure reliability and effectiveness.

1. Pricing:
   - Model System subscription-based approach with different tiers will cater to various greenhouse sizes and needs.

3. Partnerships:

- Collaborations with agricultural tech companies and greenhouse manufacturers will expand our reach and integrate seamlessly with existing systems.

4. Marketing:

- We will leverage digital marketing, industry events, and success stories to promote the system's benefits and attract potential customers.

5. Support and Training:

- Comprehensive support and training will be provided to ensure smooth implementation and user satisfaction.

We will adhere to agricultural and data protection regulations to ensure our system meets industry standards and secures user data.

10. BUDGET AND BUDGET JUSTIFICATION

Requirements		Costs (Rs.)
Category	Item Description	
Hardware	Microcontroller (ESP32)	2200.00
	Soil Moisture sensors	700.00
	Temperature & Humidity Sensor	450.00
	Light Sensors	400.00
	Ultrasonic Sensor	550.00
	DC LCD Display(5v)	750.00
	Relay Modules	250.00
	Power Supply	750.00
	Jumper Wire	600.00
	Breadboard	650.00
	Mini Water Pump	200.00
Other Charges	Travelling charges for data collection	14000.00
	Internet charges for research	5000.00
	Firebase Messaging Service	Free
	Cost of Deployment & DB	6000.00/month

Figure 8 Budget

10.1 Budget Justification

- Hardware - The components listed are essential for building the IoT system to monitor and control the greenhouse environment. The quantities are based on the need to monitor multiple parameters (e.g., temperature, humidity) and ensure redundancy in case of component failure.

- Other Charges - All required software tools are open-source, minimizing the cloud hosting is necessary for the web-based application, and a contingency budget is set aside for any unexpected costs.

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