ECO-ROVER

Capstone Project
End-Semester Evaluation

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ABSTRACT

This project introduces an agricultural rover that operates on solar power, revolutionizing wheat farming methods with sustainable technology. Made from lightweight PVC and powered by a 20W solar panel, this rover offers an environmentally friendly solution to modern agricultural challenges. It is equipped with state-of-the-art sensors (NPK, soil moisture, and DHT11) for real-time monitoring of soil and environmental conditions. The data collected is then transmitted to a mobile app operated by farmers, enabling them to make informed decisions regarding crop management. Additionally, the rover includes a precision spraying system that optimizes the use of resources. By combining solar energy, advanced sensing capabilities, and a user-friendly design, this rover represents a significant advancement in agricultural technology, aiming to enhance efficiency, reduce labor, and promote sustainable farming practices.

Mentor Consent Form

We hereby declare that the design principles and working prototype model of the project entitled ECO-ROVER is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Rajkumar Tekchandani during 7th semester (2023).

Date: 17/12/2023

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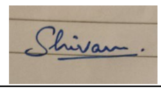
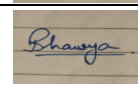
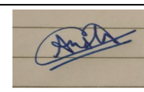
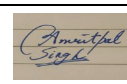
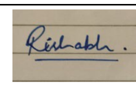
102003584	Shivam Arora	
102003676	Bhavya Jain	
102003685	Arshjeet Singh	
102003690	Amritpal Singh	
102003696	Rishabh Mohan	

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1- Introduction

1.1 Project Overview

1.1.1 Technical terminology

Solar-Powered Rover: Rover is specifically designed for agricultural purposes and relies primarily on solar energy for power.

Remote Controller: An integral component of the system, the remote controller allows farmers to operate the rover from a distance. It has a user-friendly interface and a mobile holder attached, enabling real-time data viewing and analysis.

NodeMCU: Serving as the rover's brain, the NodeMCU is a critical microcontroller board. It connects the rover's sensors and actuators to the control system, facilitating wireless communication with the mobile app.

Johnson Motors: These heavy-duty electric motors have been carefully selected for their robustness and reliability & are responsible for propelling the rover's back wheels, providing ample power to navigate the agricultural terrain and carry necessary

NPK Sensor: This sensor is of utmost importance in determining the soil's health by measuring the levels of nitrogen, phosphorus, and potassium – key nutrients for crop growth.

DHT11 Sensor: By measuring the ambient temperature and humidity, the DHT11 sensor provides vital information about the environmental conditions that impact crop growth.

Servo Motor: A motor known for its precise control capabilities. In this project, it is used to control the movement of the spraying arm, ensuring accurate and efficient spraying of water and fertilizers.

Literature Survey

1.1.2 Problem Statement

The solar-powered agricultural rover project aims to tackle various important problems in modern agriculture, specifically in growing wheat crops. These issues are complex and interconnected, affecting the effectiveness and long-term viability of farming methods. Some of the issues are listed below:

a. Modern agriculture faces challenges such as a shortage of labor and increasing operational costs. The reliance on manual labor leads to time-consuming tasks and higher expenses for farmers.

b. Traditional farming methods often result in inefficient use of vital resources like water and fertilizers. This not only increases expenses but also causes environmental issues such as soil degradation and water contamination.

c. The environmental impact of agriculture is a growing concern due to practices like excessive use of chemical fertilizers and inefficient irrigation. This unsustainable approach affects the immediate environment and the long-term health of the ecosystem.

d. Many farming practices have not integrated modern technology, limiting efficiency and productivity. The slow adoption of technology hinders innovation and improvement in farming methods.

e. Effective monitoring and maintenance of crops are crucial for healthy growth and yield. However, manual monitoring is labor-intensive and imprecise. There is a need for a more efficient and accurate way to gather data on soil conditions, moisture levels, and environmental factors that affect crop health.

1.1.3 Goals

a. To automate the process of crop monitoring and maintenance. Traditional farming methods are labor-intensive and inconsistent, leading to inefficiencies and potential crop losses. By automating these processes, the project aims to reduce physical labor and help farmers manage their crops more effectively. This automation is particularly important for monitoring soil conditions, environmental factors, and applying necessary treatments to ensure optimal crop growth and yield.

b. To get precise application of essential resources like water and fertilizers. The rover is equipped with advanced sensors and a precision spraying system, allowing for targeted application based on real-time soil and environmental data. This ensures that crops receive exactly what they need and minimizes resource wastage.

c. Using solar energy to power the rover, aligning with global initiatives to reduce reliance on fossil fuels and minimize carbon emissions. By harnessing solar power, the rover operates in an eco-friendly manner, showcasing the effectiveness of renewable energy in agriculture. This goal reflects a commitment to sustainable development in agriculture, reducing the sector's environmental footprint.

d. The rover is designed to collect real-time data on parameters like soil moisture, nutrient levels, and environmental conditions. This data is crucial for making informed decisions about crop management.

1.1.4 Solution

The design and construction of the rover prioritize both lightweight and sturdy materials, utilizing PVC pipes for its frame. This choice ensures that the rover can easily maneuver through various agricultural terrains while maintaining durability. Standing at a height of 3 feet, the rover is specifically designed to optimize its functionality in wheat fields.

To power the rover, a 20W solar panel is incorporated, which charges a bank of batteries connected in parallel. This setup provides the rover with a sustainable energy source, making it eco-friendly and efficient in energy consumption.

For mobility and stability, the rover is equipped with 2 heavy-duty Johnson motors to power the back wheels. This configuration allows the rover to navigate the fields effectively and carry out its task easily.

In terms of control and monitoring, the rover is operated through a remote controller that includes a mobile holder. This design enables farmers to control the rover while simultaneously monitoring soil conditions and other relevant data through a mobile app.

The NodeMCU micro-controller board plays a crucial role in transmitting data from the rover's sensors to the mobile app, facilitating real-time monitoring and analysis.

To ensure accurate assessment of soil conditions, the rover consists of sensors, including NPK and DHT11 sensors. These sensors provide vital data on soil moisture, nutrient levels, temperature, and humidity.

A notable feature of the rover is its separate 10-liter water tank and spraying arm, which can move up and down 180 degrees. Powered by a servo motor, this arm helps in precise spraying of water/fertilizers.

1.2 Need Analysis

Conventional farming practices often result in excessive use of water, fertilizers, and energy, leading to wastage and ecological damage. The project aims to address this issue by incorporating sensors that provide real-time data on soil conditions, enabling targeted spraying and minimizing waste while improving the health of crops.

Remote control capabilities allow farmers to manage the rover from a distance, reducing the need for manual intervention and freeing up time for other important tasks.

Modern agriculture necessitates precise crop management for optimal yields. By integrating sensors such as soil moisture, temperature, and humidity sensors, the project fulfills the need for accurate data collection. This data empowers farmers to make informed decisions regarding irrigation and fertilization strategies.

Environmental Sustainability: The agricultural sector's impact on the environment calls for sustainable practices. The project addresses this need by utilizing solar energy to power the rover, reducing reliance on fossil fuels. This aligns with global efforts to promote eco-friendly farming practices.

Real-time Monitoring: Access to instant crop data greatly enhances decision-making. The mobile app's real-time data feed satisfies the need for immediate monitoring. Farmers can remotely assess soil conditions and adjust the rover's operations accordingly, enabling timely and well-informed interventions.

Crop Diversification: Different crops have unique requirements. The project's adaptable design and potential for expansion cater to the need for versatility. The rover's architecture can be modified to accommodate a wide range of crops, extending its applicability beyond just wheat.

1.3 Research Gaps

Our project focuses on gathering data and monitoring it in real-time, still; there is a potential research void in investigating the incorporation of artificial intelligence (AI) algorithms to enhance decision support. By integrating AI, it becomes possible to utilize predictive modeling for optimizing irrigation and fertilization strategies, taking into account historical data patterns and current conditions.

Reference: Sengar, S. S., & Shukla, A. (2019). An Overview of Artificial Intelligence in Agriculture. Journal of Advanced Research in Dynamical & Control Systems, 11(7), 916-921.

The main goal of the project is to improve mobility in agricultural fields. However, there is potential for additional research to be done on adaptive navigation techniques. These techniques would enable the rover to navigate complex terrains, including uneven landscapes and areas with obstacles. To achieve this, advanced sensor fusion and path planning algorithms could be utilized.

Reference: Bhowmik, P., & Ghosh, D. (2018). Terrain Mapping, Path Planning and Obstacle Avoidance of a Solar Powered Robot. Procedia Computer Science, 132, 950-957.

Although solar energy plays a crucial role, there exists a research gap in exploring the most effective approaches for managing energy. This research could focus on finding the right balance between energy usage for mobility, sensor functionality, and recharging to ensure extended rover operations without depleting the battery reserve.

Reference: Zheng, J., & Wen, F. (2019). Optimal Energy Management of a Solar-Powered Electric Vehicle Charging Station Based on MPC Strategy. IEEE Transactions on Industry Applications, 55(6), 6272-6282.

The project utilizes various sensors to gather data, however, different crops may require specific sensor calibration. Additional research could focus on calibrating these sensors for different types of crops, considering differences in soil properties and environmental conditions.

Reference: Dikshit, A., & Das, A. B. (2020). Calibration and Comparative Study of Soil Moisture Sensors for Precision Agriculture. IOP Conference Series: Materials Science and Engineering, 972(1), 012112.

The research project could benefit from investigating user experience (UX) aspects like interface design, ease of use, and feedback mechanisms. This could help identify any gaps in the current mobile app's remote control functionality. By optimizing the app's UX, farmers' interaction with the rover can be improved, leading to better overall usability.

Reference: Kujala, S., Roto, V., Väänänen-Vainio-Mattila, K., Sinnelä, A., & Lehtinen, T. (2011). UX curve: A method for evaluating long-term user experience. Interacting with Computers, 23(5), 473-483.

1.4 Problem Definition and Scope

Problem Definition

The challenges faced by modern agriculture hinder efficient crop management, resource utilization, and sustainability. Conventional methods often involve labor-intensive processes, imprecise resource application, and limited real-time crop monitoring. These limitations result in resource wastage, reduced yields, and environmental degradation. Therefore, there is a need for an innovative solution that utilizes technology to enable remote monitoring, precise resource allocation, and eco-friendly practices. This will ultimately enhance crop yields while minimizing environmental impact.

Scope

Our Project aims to tackle these challenges by designing and developing an autonomous rover equipped with advanced technologies. The project's scope includes:

1. The rover's structure, which will be designed using lightweight materials like PVC pipes to ensure portability and minimal soil compaction. Additionally, a 20W solar panel will be integrated for energy harvesting, along with a battery bank for sustainable power supply.

2. A mobility system, which is implemented, utilizing heavy-duty Johnson motors for rear wheel movement and dummy motors for balance. This will enable the rover to navigate agricultural fields effectively.

3. A precise spraying arm, which is designed, incorporating a servo motor for targeted application of water and fertilizers. Soil sensors (NPK and DHT11) will also be integrated to optimize resource allocation based on real-time soil conditions.

4. Soil moisture, temperature, and humidity sensors are integrated to collect environmental data. A NodeMCU module will be employed for data transmission to a mobile app.

5. A user-friendly, Open-Source mobile app will be used to remotely control the Wter-Proof Servo-motor used to pump the water/pesticides. Real-time sensor data will be displayed on the app for monitoring crop health and making informed decisions.

6. Sustainability and Future Prospects: The project will explore opportunities for integrating AI algorithms to enhance decision support and further minimize environmental impact.

1.5 Assumptions and Constraints

Table 1

S. No.	Sample Assumptions
1	Stable Terrain: The project assumes relatively stable and even terrain in the agricultural fields where the rover will operate. Terrain with extreme slopes, obstacles, or challenging conditions might require further modifications to the rover's mobility and navigation systems. Standardized Sensor Calibration: The sensors used in the project are assumed to be calibrated according to standard specifications. Customized calibration for specific soil types or crops is not considered within the project scope.
2	Steady Sunlight Exposure: The solar panel's performance relies on consistent exposure to sunlight. The project assumes that the rover will operate in regions with sufficient sunlight throughout the day for effective energy harvesting. Appropriate Weather Conditions: The project assumes typical weather conditions for agricultural regions, including moderate wind and temperature levels. Extreme weather conditions might impact the rover's operations and energy efficiency.
3	**Constraints** Power Limitations: The rover's operational time is constrained by the capacity of the battery bank and solar panel efficiency. Longer operation times might require larger battery capacity and more efficient energy harvesting solutions. Payload Capacity: The rover's payload capacity is constrained by its design and motor capabilities. Transporting heavy payloads beyond the design limits could affect the rover's stability and mobility.
4	Communication Range: The remote control and data transmission capabilities of the rover are constrained by the range of the wireless communication modules. Operating beyond this range might result in loss of control or data transmission. Mobile App Compatibility: The mobile app is constrained by the compatibility of users' smartphones and operating systems. Compatibility issues might limit the app's accessibility for some users.

1.6 Standards

Here are some relevant standards that we've considered:

ISO 9001: Quality Management Systems:
This standard provides a framework for quality management across various industries. Adhering to ISO 9001 principles has made sure our project follows best practices in design, manufacturing, and quality control.

ISO 14001: Environmental Management Systems:
Our project emphasizes sustainability, so ISO 14001 provides guidelines for environmental management. This standard helped us implement processes that minimize the project's ecological footprint.

ISO 26262: Functional Safety for Automotive Applications:
This standard provided us principles for ensuring the functional safety of systems, including robotics. It assisted us in designing the rover's autonomous features to ensure safe operation.

IEC 60950-1: Information Technology Equipment - Safety:
Our project involves electronic components, so this standard outlines safety requirements for IT equipment, including electrical safety considerations.

IEC 60529: Degrees of Protection Provided by Enclosures (IP Code):
This IEC standard provided us specifications for the protection against intrusion of solids and liquids in electrical enclosures.

ASTM E3126: Standard Guide for Validating Environmental Performance Claims:
This standard guided us on validating environmental claims, which are relevant as our project aims to make specific sustainability claims.

1.7 Approved Objectives

1. To Design and build a sturdy and lightweight rover structure using PVC pipes to ensure stability, portability, and minimal soil compaction during field navigation.

2. To incorporate a 20W solar panel and a battery bank consisting of parallel-connected batteries to provide sustainable and eco-friendly power for the rover's operations.

3. To implement a mobility system using heavy-duty Johnson motors for rear wheel propulsion and dummy motors for balance, enabling effective navigation across agricultural fields.

4. To integrate soil moisture, temperature, and humidity sensors to collect real-time environmental data. Use a NodeMCU module for data transmission to facilitate remote monitoring.

1.8 Methodology

a. Extensive research and planning were conducted in the initial phase to gain a comprehensive understanding of the specific requirements of wheat farming and the challenges faced by farmers. This stage involved careful selection of suitable materials and components for constructing the rover, such as PVC pipes for the frame, an efficient solar panel for energy conservation, and robust motors for seamless movement. The objective of the design was to create a lightweight, durable, and energy-efficient rover capable of performing a range of agricultural tasks.

b. Construction and Assembly: Following the design phase, the construction of the rover commenced. This involved the meticulous assembly of the PVC frame, integration of the solar panel with the battery bank, and installation of the motors. Special attention was given to ensure the rover's mobility and balance, enabling it to navigate diverse terrains while carrying essential equipment like the water tank and spraying arm.

c. The subsequent crucial step involved integrating the control and sensing systems. The rover was equipped with a NodeMCU microcontroller to facilitate seamless communication between the sensors, the remote controller, and the mobile app. Sensors such as NPK and DHT11 were installed to measure soil conditions, while the servo motor was configured to control the movement of the spraying arm.

d. The development of software for the remote controller and mobile app was undertaken. The software was designed with a user-friendly interface, providing real-time data visualization and analysis. This enabled farmers to make informed decisions based on the data collected by the rover's sensors.

e. After completion of the assembly and software development, rigorous testing of the rover was conducted. This included field tests to evaluate the rover's maneuverability, battery life, and the functionality of the sensors and spraying system. Calibration of the sensors and fine-tuning of the control systems were also carried out to ensure precise and accurate performance.

1.9 Project Outcomes and Deliverables

Our project aims to achieve a series of significant outcomes and produce valuable deliverables. The foremost deliverable is the development and deployment of a fully functional solar-powered agricultural rover. This rover, designed to be robust and operational, is equipped with solar panels, a battery bank, advanced sensors, and a precision spraying system, symbolizing a tangible, eco-friendly innovation in agricultural tools. The primary outcome of this deliverable is to provide farmers with a practical means to automate crop monitoring and maintenance, thereby enhancing agricultural efficiency.

In addition to the rover itself, another key deliverable is the advanced sensing and data collection capabilities integrated within the rover. These include NPK, DHT11, and soil moisture sensors, all transmitting real-time data to a mobile app for efficient monitoring. The outcome here is the empowerment of farmers with access to vital information regarding soil and environmental conditions, enabling data-driven decision-making in farming practices.

An important aspect of our project is the precision spraying mechanism. The deliverable in this area is a sophisticated spraying arm, controlled by a servo motor and equipped with adjustable nozzles for precise application. This leads to an important outcome: the optimization of resource utilization, specifically water and fertilizers, reducing wastage and mitigating environmental impacts.

Moreover, our project delivers a user-friendly remote operation and monitoring system, including a custom-designed mobile app for data visualization. This system simplifies the operation of the rover and allows farmers to remotely manage their crops, a significant outcome in terms of enhancing convenience and efficiency in agricultural operations.

Promoting sustainable agricultural practices is another crucial outcome of our project. Demonstrating the practical use of renewable energy in agricultural operations aligns with global sustainability goals, showcasing an environmentally responsible approach to farming.

1.10 Novelty of Work

a. The combination of precision spraying arm and soil sensors (NPK and DHT11) distinguishes our project. By utilizing real-time soil conditions, it optimizes water and fertilizer usage for better crop health.

b. Offering a user-friendly mobile app for remote control and real-time monitoring is a unique feature that empowers farmers. It allows them to conveniently manage their crops and make informed decisions from a distance, enhancing efficiency.

c. By integrating a 20W solar panel and battery bank, our project showcases a focus on sustainability. Using solar energy as a power source aligns with eco-friendly practices and reduces reliance on fossil fuels.

d. The groundbreaking approach of using real-time sensor data to optimize resource allocation is a significant advancement in precision agriculture. It enables the rover to make informed decisions about water and fertilizer application based on accurate data.

e. Your project's adaptable design allows for cultivation beyond wheat. The rover's versatility in catering to different crop types and terrains adds a novel layer of flexibility.

2.1 Literature Survey

2.1.1 Related Work

Here are some of the realted work/systems:

a. Rowbot Systems has created a self-governing robot that is specifically designed to transport fertilizer directly to the roots of crops. This innovative robot is able to navigate through crop rows and apply fertilizer based on real-time soil data.

b. Blue River Technology, which was acquired by John Deere, has developed the See & Spray technology. This advanced system utilizes cameras to identify and accurately apply herbicides to weeds, while ensuring that crops are not affected.

c. Climate FieldView offers farmers a comprehensive platform to monitor and manage their fields. This platform provides real-time data on soil conditions, weather patterns, and crop health, empowering farmers to make informed decisions.

d. Agrivi is an agricultural management platform that integrates data from various sources to provide valuable insights into crop health, growth stages, and pest management. It also enables remote monitoring and collaboration among farmers.

e. Case IH has successfully created an autonomous tractor that is capable of performing a range of tasks including planting, seeding, and tillage. This tractor utilizes GPS technology to ensure precise navigation and efficient operations.

f. ecoRobotix has developed an autonomous robotic sprayer that is specifically designed for the precise application of herbicides. By utilizing cameras, this robotic sprayer is able to identify and target weeds, resulting in reduced chemical usage.

g. Rain Bird's IC System utilizes IoT-enabled controllers and sensors to monitor weather conditions and soil moisture levels. This system enables smart irrigation management, ensuring that crops receive the appropriate amount of water based on real-time data.

2.1.2 Research Findings for Existing Literature

Table 2

S. No.	Roll Number	Name	Paper Title	Tools/ Technology	Findings
1	102003584	Shivam	Lalwani, Ashish et al.	Autonomous Robotics	reduced labor costs, and minimized environmental impact
2	102003676	Bhavya	Giuseppe Quaglia et al.	precision agriculture	improve sustainability reducing the use of fossil fuels.
3	102003685	Arshjeet	Héctor Cadavid et al.	cloud-based Smart Farming platform	concentrate sensors, a decision support system, & configuration of remotely controlled devices
4	102003690	Amritpal	Giles, D., et al.	Advanced sprayer technology	reduction in water/pesticide application rates by 15% - 40% .
5	102003696	Rishabh	Blue River Technology	See & Spray Technology	help farmers to reduce use of chemicals & increase the yields.

2.1.3 Detailed Problem Analysis

a. Traditional agricultural practices often lead to ineffective management of resources, such as water and fertilizers. The uniform distribution of resources across large fields results in wastage, reduced crop health, and increased environmental impact. This has led to excessive use of water and fertilizers, which not only increases production costs but also contributes to water scarcity and pollution. Inadequate distribution of resources can compromise crop yield and quality.

b. Managing large agricultural fields requires significant labor for tasks like monitoring, irrigation, and fertilization. The manual nature of these tasks makes them labor-intensive, time-consuming, and challenging to handle, especially in remote or expansive areas which has led to higher labor costs and potential inconsistencies in resource application. The remote accessibility of fields for monitoring and management further exacerbates these challenges.

c. Farmers often lack timely and accurate information about the condition of their crops, making it difficult to make informed decisions regarding irrigation, fertilization, and pest management. The absence of real-time data hinders optimal crop care that results in struggle of farmers to respond promptly to changing environmental conditions, leading to suboptimal allocation of resources and potential crop loss. Inaccurate decisions can significantly impact yield and profitability.

2.1.4 Survey of Tools and Technologies Used

a) ArduinoIDE is used for the purpose of controlling various components, integrating sensors, and processing data. It also provides a simple and easy-to-use interface for writing code in the Arduino programming language (C,C++).

b) We've made use of NodeMCU which enables the configuration of the microcontroller through the Arduino IDE and facilitates the transfer of data via WiFi to the IoT Hub.

c) A 24W Solar Panel is employed to harness solar energy, which is then utilized to power the rover. The Battery Bank consists of batteries connected in Series, serving as an energy storage solution.

d) Two Johnson heavy duty Motors are responsible for propelling the back wheels of the rover, ensuring its mobility. Additionally, a Servo Motor is utilized to control the movement of the spraying arm.

e) The Soil Moisture Sensor is utilized to measure the moisture levels present in the soil. A Temperature and Humidity Sensor is employed to monitor the environmental conditions. Furthermore, a Light Sensor is used to measure the intensity of light.

f) For wireless communication between the rover and the mobile app, we've used NodeMCU (ESP8266), which has built in Wi-Fi interface(2.4Ghz) . We've used this setup to enable remote control and data transmission.

g) PVC Pipes are utilized to construct the rover's lightweight and sturdy structure. Spraying Nozzles are employed to apply fertilizers and water to crops.

2.1.5 Summary

Our project is built on the foundations of precision agriculture, leveraging cutting-edge sensors and data analysis to enhance the utilization of vital resources such as water and fertilizers. This strategy aligns with established methodologies that prioritize efficiency and targeted resource allocation.

Our efforts have helped incorporate automation into farming. While the utilization of remotely operated vehicles in agriculture is not novel, our project takes these concepts further by extending and refining their implementation.

Here are some key factors that differentiate our work from the works that have been done before:

a. Solar power sets this project apart, as it utilizes renewable energy instead of fossil fuels, reducing its environmental impact. Unlike traditional agricultural machines, this rover is dedicated to sustainability.

b. This project goes beyond basic automation by incorporating a user-friendly remote control system with a mobile app. This integrated system allows for real-time data monitoring and analysis, a feature not commonly found in existing agricultural machinery.

c. Unlike other agricultural technologies, this rover is specifically designed for wheat farming. Its design, sensor selection, and functionality are all optimized to meet the unique requirements of managing wheat crops.

d. This project strikes a balance between technological sophistication and user accessibility. The rover is not only advanced but also practical and easy to operate for farmers, regardless of their technical expertise.

2.3 Software Requirement Specifications

2.1 Introduction

2.3.1.1 Purpose

The main objective SRS is to present a comprehensive overview of the software system that will be created for our solar-powered agricultural rover. This involves describing the software's functionality, interfaces, user interactions, and system requirements that are essential for the rover to operate effectively. The SRS is intended to guarantee that all parties involved have a thorough comprehension of the software's capabilities and limitations, enabling effective communication and alignment of expectations between the development team & users.

2.3.1.2 Intended Audience and Reading Suggestions

a. The group of software engineers and developers who will be directly involved in coding and implementing the system. Their main focus should be on the technical specifications and requirements of the software.

b. Project Managers: Responsible for overseeing the progress of the project and ensuring that the software development aligns with the overall project objectives. They should carefully consider the project scope and requirements in order to effectively manage resources and timelines.

d. End-Users (Farmers): The primary users of the rover. While they may not require an in-depth technical understanding, having an overview of the software's capabilities and user interface would be beneficial for them.

e. Stakeholders/Investors: Individuals or groups with a vested interest in the project. It is essential for this group to have a general understanding of the software's purpose, scope, and potential impact.

2.3.1.3 Project Scope

a. The software needs to have the ability to gather data from various sensors such as NPK, soil moisture, and DHT11. This data should then be transmitted to a mobile app in real-time for analysis.

b. Users should be able to remotely operate the rover through the software. This includes navigation controls as well as the ability to operate the spraying system.

c. The mobile app should have a user-friendly interface that allows users to easily view data, control the rover, and make informed decisions regarding crop management.

d. The software should include features that allow for the analysis of collected data. It should also be able to generate reports that can assist in agricultural decision-making.

e. The software must operate consistently under varying conditions without any failures and should be intuitive and easy to use, even for individuals with limited technical expertise.

f. The software should have the ability to adapt and upgrade to meet future requirements or integrate additional features and should be designed within the limitations of the rover's hardware capabilities.

g. Data integrity and privacy should be safeguarded, especially during data transmission and storage.

2.3.2 Overall Description

2.3.2.1 Product Perspective

The solar-powered agricultural rover is a self-contained robotic system designed to operate within agricultural fields. It interacts with both the physical environment and the end-users through a combination of hardware and software components.

The rover is intended to enhance crop monitoring and management, allowing farmers to make informed decisions remotely. It operates autonomously within predefined boundaries and can be controlled and monitored using a mobile app.

The rover's software and hardware components work in harmony to achieve the project's objectives. The hardware includes the chassis made of PVC pipes, solar panels, battery banks, motors, spraying arm, and sensors.

The software encompasses the wireless communication protocols, and the mobile app interface. Together, these elements create a complete system that optimizes resource utilization, promotes sustainability, and provides valuable data insights to improve crop health.

2.3.2.2 Product Features

Our rover is powered by a solar panel, which is a crucial component. This sustainable energy source ensures that the rover operates in an eco-friendly manner and also helps in reducing operational costs.

Advanced Sensor Suite: The rover is equipped with various sensors such as NPK, DHT11, and soil moisture sensors. These sensors enable the rover to collect important data on soil health and environmental conditions, which is essential for precision farming.

Remote Control and Operation: The rover can be operated remotely using a controller that has a mobile holder. This feature allows for easy maneuvering and control of the rover while simultaneously monitoring the collected data.

Precision Spraying System: The rover is equipped with a sophisticated spraying arm that can make precise movements. This arm is controlled by a servo motor, ensuring accurate application of water and fertilizers.

Real-Time Data Transmission and Analysis: The data collected by the rover's sensors can be transmitted in real-time to a mobile app. This app allows for the analysis of the data, which can then be used to make informed farming decisions.

Durable and Maneuverable Design: The rover is constructed using lightweight PVC, making it both durable and agile. This design enables the rover to navigate different terrains in agricultural fields.

Scalability and Customization: The rover is designed with scalability in mind, allowing it to be adapted or upgraded to meet the requirements of different farming sizes and types of crops.

User Interface (UI): The accompanying mobile app features a user-friendly interface, making it accessible to farmers with varying levels of technological expertise.

2.3.3 External Interface Requirements

2.2.3.1 User Interface

Mobile App Interface

The mobile application functions as the main interface for managing the solar-powered agricultural rover, overseeing crop conditions, and obtaining data analysis.

The app's interface will also showcase real-time sensor data including soil moisture, temperature, humidity, soil nutirent conditions.

The app shall make use of Mobile's hotspot internet to operate and get connected to the rover.The app also controls the water pump via which spraying arm sprays the fertilizers/water.

Remote Controller Interface

The physical remote controller comprises of buttons and a mobile holder, allowing for the simultaneous control of the rover and viewing of data.

The basic rover movement commands shall be facilitated through buttons on the remote controller.

For convenient data viewing, the mobile holder shall securely accommodate smartphones of different sizes.

The operational status of the rover, including power and connectivity, shall be indicated by LED indicators.

2.3.3.2 Hardware Interface

Sensor Integration

The rover integrates multiple sensors to gather data and tell the farmers to make informed decisions.

The microcontroller establishes a connection with the sensors (soil moisture, temperature, humidity, light intensity) through suitable analog or digital interfaces.

At specific intervals, the sensor data needs to be gathered and sent to the microcontroller for further analysis and processing.

Communication Modules

The rover establishes wireless communication with the mobile application to enable remote control and transmission of data.

The wireless communication module of the rover, such as Wi-Fi or Bluetooth, is required to connect with the microcontroller in order to exchange data.

It is essential for the communication module to ensure secure and dependable transmission of data to and from the mobile app.

2.2.3.3 Software Interface

Mobile App Communication

The rover is connected to the mobile app, allowing for control and data transmission. The application is required to establish a wireless connection with the communication module of the rover by utilizing suitable protocols.

The rover's microcontroller will interpret the control commands (related to movement and arm control) transmitted from the application.

Furthermore, the sensor data gathered by the rover will be transmitted to the application in order to provide real-time visualization.

Data Analysis and Visualization

The software module analyzes and displays sensor data to provide valuable information for users.

The sensor data will be processed by the microcontroller and transformed into units that can be easily understood by humans.

The processed sensor data will be organized in a format suitable for presentation on the user interface of the mobile app.
The mobile app will display historical sensor data using graphs or charts to analyze trends.

2.3.4.1 Performance Requirements

The rover should have the capability to function for a specified duration (e.g., 40 minutes) on a single charge. Efficiently harnessing and storing solar energy, the solar panel and battery system must provide a sustainable power source with sufficient recharging capability.

Accurate readings within a defined margin of error must be provided by sensors, including NPK, soil moisture, and DHT11 and these sensors should reliably operate in various environmental conditions commonly found in wheat farming settings.

Data must be transmitted to the mobile app by the rover in real-time or within an acceptable delay threshold. The system should process and analyze sensor data quickly, enabling farmers to make timely decisions.

The rover should effectively navigate over typical agricultural terrains, including uneven surfaces and the control system must allow precise and responsive maneuvering of the rover in the field.

The precision spraying system should accurately target specified areas, minimizing the waste of resources such as water and fertilizers & should be capable of adjusting spray patterns or volumes based on data received from the sensors.

The rover must be constructed to withstand the typical wear and tear of agricultural environments, including exposure to elements like dust, water, and varying temperatures.
All components, including motors, chassis, and electronics, should be durable and require minimal maintenance.

The mobile app and remote controller interface should be responsive, with minimal lag in user input and system reaction. The UI should clearly display real-time data and promptly update as new data is received.

2.3.4.2 Safety Requirements

In order to prioritize safety, both the remote controller and the mobile app must incorporate a prominent emergency stop button. This button, when pressed by the farmer, will immediately halt all movements and operations of the rover.

To ensure safe usage of the rover in the field, it is imperative that the user manual and mobile app offer clear instructions on proper operating practices and guidelines. These guidelines will equip the farmer with the necessary knowledge to operate the rover safely.

To prevent any accidental collisions and guarantee personal safety, the user manual should clearly specify a safe operating distance between the farmer and the rover. Adhering to this distance will minimize any potential risks.

To safeguard both the rover and the farmer, it is strongly advised in the user manual to refrain from operating the rover during adverse weather conditions such as heavy rain or storms. This precautionary measure will prevent any damage to the rover and ensure the safety of the farmer.

The user manual should include comprehensive guidelines for the safe operation of the spraying arm. These guidelines should emphasize the importance of maintaining a safe distance from the arm during movement and avoiding any contact with crops. By following these precautions, the farmer can ensure their own safety and prevent any potential damage to the crops.

To mitigate any electrical hazards or shocks, the rover's electrical components must be properly insulated and sealed. This precautionary measure will effectively prevent any potential electrical hazards and ensure the overall safety of the farmer.

2.2.4.3 Security Requirements

User Authentication: To ensure that only authorized individuals can access the rover controls and data, the mobile app will incorporate user authentication, requiring users to provide a username and password.

Data Encryption: To safeguard against unauthorized interception or tampering of data, secure protocols will be employed to encrypt the data exchanged between the rover and the mobile app.

Remote Access Controls: The mobile app will feature access controls that enable the owner of the rover to manage access permissions for other users, granting or revoking their access as needed.

Firmware Integrity: To maintain the integrity of the rover's microcontroller firmware, it will be digitally signed, ensuring its authenticity and preventing any unauthorized modifications.

Secure Communication: To protect the transmission of data between the rover and the mobile app, the wireless communication module will utilize secure encryption protocols, ensuring the security of the communication channel.

2.3 Cost Analysis

Solar Panel: Rs. 4000
Batteries (x2): Rs. 2000
CV PVC Structure: Rs. 1500
Soil Moisture Sensor: Rs. 200
NPK Sensor: Rs. 5500
Temperature and Humidity Sensor: Rs. 200

60 RPM Motors (x2): Rs. 1500

DHT11 Sensor- Rs. 250
Tyres (x4): Rs. 1500
Water Pump (12V/8W): Rs.500
BMS Controller: Rs. 300
Motor Driver: Rs. 500

FC28 sensor- 200

Miscellaneous - 14`00

Total Cost: Rs. 20000

2.5 Risk Analysis

Data Security Breach which Impacts user data due to compromize and loss of trust whose likelihood is very High. Remedy includes implementing strong data encryption, conduct security audits, and keep software updated.

Unstable Wireless Communication which Impacts control through disruption, and loss of data whose likelihood is Medium. Mitigation steps include choosing reliable communication modules, testing communication range extensively, and implementing error correction mechanisms.

Weather-Related Damage which Impacts rover and components causing damage whose Likelihood is High. Remedy steps include Avoiding operation during adverse weather conditions, providing protective covers when not in use.

User Error in Remote Control which Impact via Accidents, damage to crops whose Likelihood is very High. Remedy includes Implementing emergency stop mechanisms, providing comprehensive user training, and simplifying the control interface.

Limited Battery Life impacts operational time, interruption in field operations. whose Likelihood is Medium. Mitigation steps are: Optimize energy consumption, provide guidelines for efficient battery usage.

Mobile App Compatibility Issues Impact: User mindset, reduced functionality whose Likelihood is Medium. Remedy includes Testing the app on various devices and operating systems, addressing compatibility issues promptly.

3.1 Investigative Techniques

Justification

The solar-powered agricultural rover project utilizes a blend of field research and user feedback collection as its investigative technique. This approach is justified by its direct applicability to real-world agricultural practices. Through field research, valuable insights into the practical obstacles and requirements of modern wheat farming will be gained, enabling the rover's design and functionalities to be customized for optimal performance in actual farming scenarios. User feedback, specifically from farmers, will provide valuable viewpoints on the rover's usability and effectiveness, facilitating iterative enhancements and guaranteeing that the final product meets user expectations and fulfills their needs.

Methodology

The solar-powered agricultural rover's development follows a streamlined methodology consisting of several key phases to maximize efficiency and effectiveness. Initially, field research is conducted, which involves visiting farms to gain an understanding of current agricultural practices and environmental conditions. This ensures that the design of the rover closely aligns with the real-world needs of farmers.The data collected throughout the process is analyzed to identify trends and areas for improvement. This analysis culminates in comprehensive reports that inform the final development of the rover. The goal is to ensure that the rover is technologically robust, user-friendly, and specifically tailored to meet the needs of modern wheat farming.

3.2 Proposed Solution

The proposed solution is focused on the development of an agricultural rover that is powered by solar energy. This rover will be equipped with advanced hardware and software components to enhance precision farming practices. Its main goal is to enable farmers to remotely monitor their crops, make data-driven decisions, and optimize resource utilization for sustainable and efficient cultivation. By integrating cutting-edge technology, this solution aims to address the challenges faced in modern agriculture, promoting productivity and environmental responsibility.

The key components and functionalities of this solar-powered agricultural rover include a chassis and mobility system. The chassis is constructed using lightweight and durable PVC pipes, providing structural integrity while minimizing weight. The mobility system consists of heavy-duty motors and wheels, allowing for efficient movement across diverse terrains. Advanced control algorithms will enable autonomous navigation, ensuring that the rover can traverse the fields while avoiding obstacles.

Energy management is another important aspect of this solution. A 24W solar panel is integrated onto the rover's structure, capturing sunlight and converting it into electrical energy. This sustainable energy source powers the rover's operations and charges a battery bank, ensuring continuous operation and reducing dependence on conventional power sources.

Precision spraying arm mechanism has the capability to move up and down and is equipped with spraying nozzles for targeted application of fertilizers and water. Additionally, the arm incorporates NPK and DHT11 soil sensors for real-time soil condition analysis, optimizing the spraying process. This feature minimizes resource wastage and improves crop health.

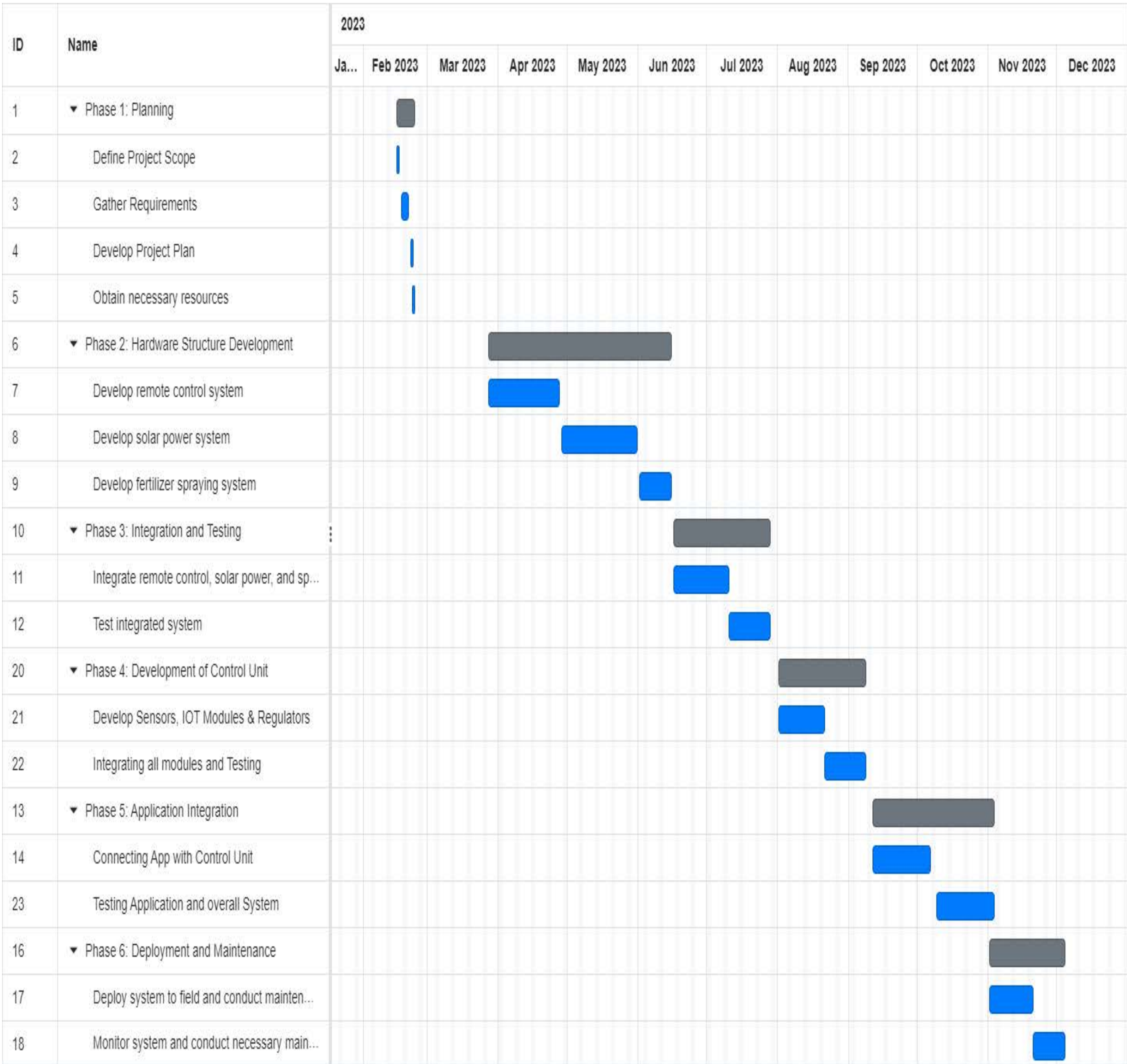
Overall, this solar-powered agricultural rover with its advanced hardware and software components offers a comprehensive solution for precision farming. It enables farmers to remotely monitor their crops, make data-driven decisions, and optimize resource utilization, ultimately promoting sustainable and efficient cultivation practices.

Microcontroller Programming is at the core of the rover's intelligence. A customized firmware will be created to effectively manage the rover's movements, arm positioning, and processing of sensor data. The microcontroller plays a crucial role in processing data from soil sensors and coordinating control commands from the user interface.

For **user-friendly experience,** a mobile app will serve as the primary interface for controlling the rover and accessing real-time data. This app will allow farmers to remotely control the rover's movements, adjust the positions of the spraying arm, and receive sensor data on soil moisture, temperature, humidity, and light intensity. Additionally, the integration of a mobile holder on the remote controller will enable simultaneous control and data viewing.

Wireless communication modules will be utilized to connect the rover with the mobile app to ensure seamless communication. This will enable real-time data exchange, control commands, and status updates. Communication protocols will be implemented to ensure the security and reliability of data during transmission.

3.3 Work Breakdown Structure



WBS GANNT CHART

3.4 Tools and Technologies Used

The operation of the rover is primarily controlled by electronics and control systems, which make use of Arduino microcontroller for processing and controlling functions.

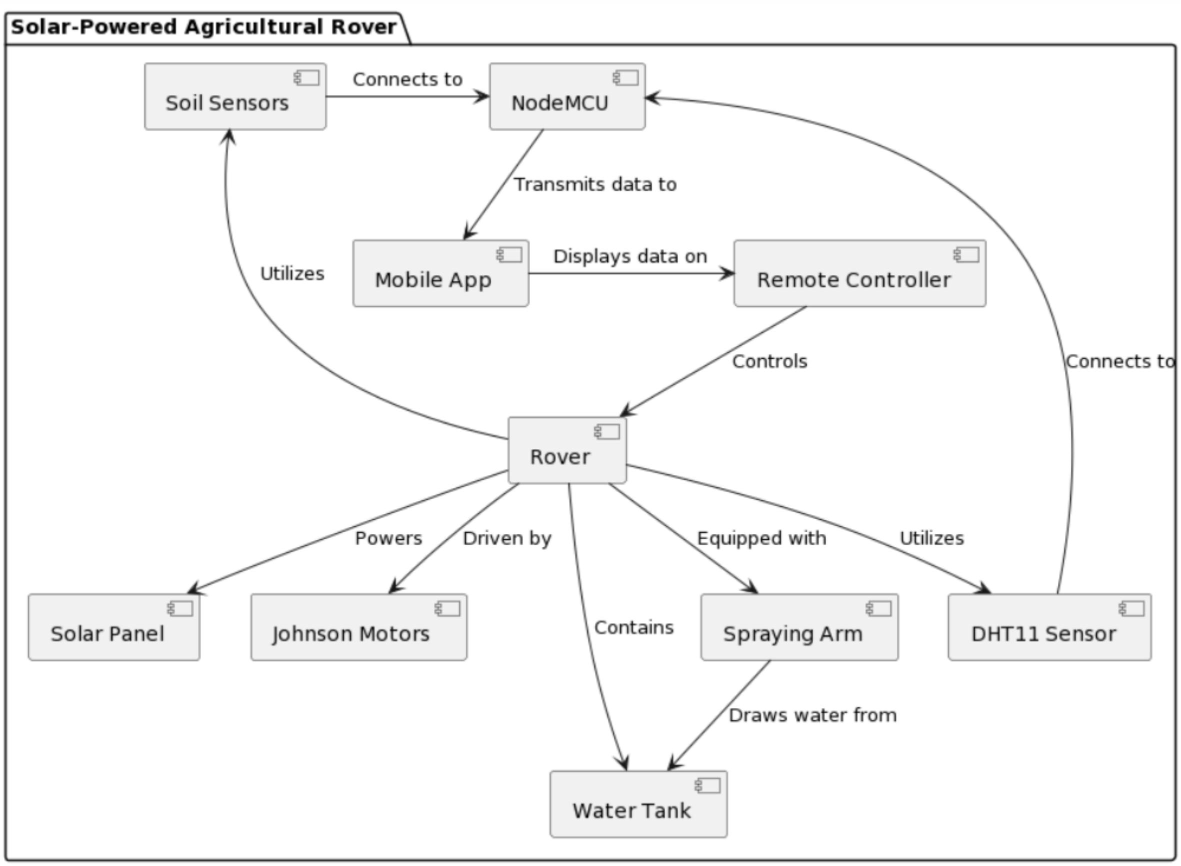
The NodeMCU (ESP 8266) module plays a vital role in facilitating IoT connectivity, allowing for real-time transmission of data to a mobile app that is specifically designed for this purpose.

The precise movement and functioning of the rover's mechanical components, particularly the spraying arm, are achieved through the use of servo motors.

The rover is furnished with a variety of sensors to facilitate environmental interaction and data collection. To monitor soil health, NPK and moisture sensors are employed, while environmental conditions such as temperature and humidity are tracked through the utilization of sensors like the DHT11.

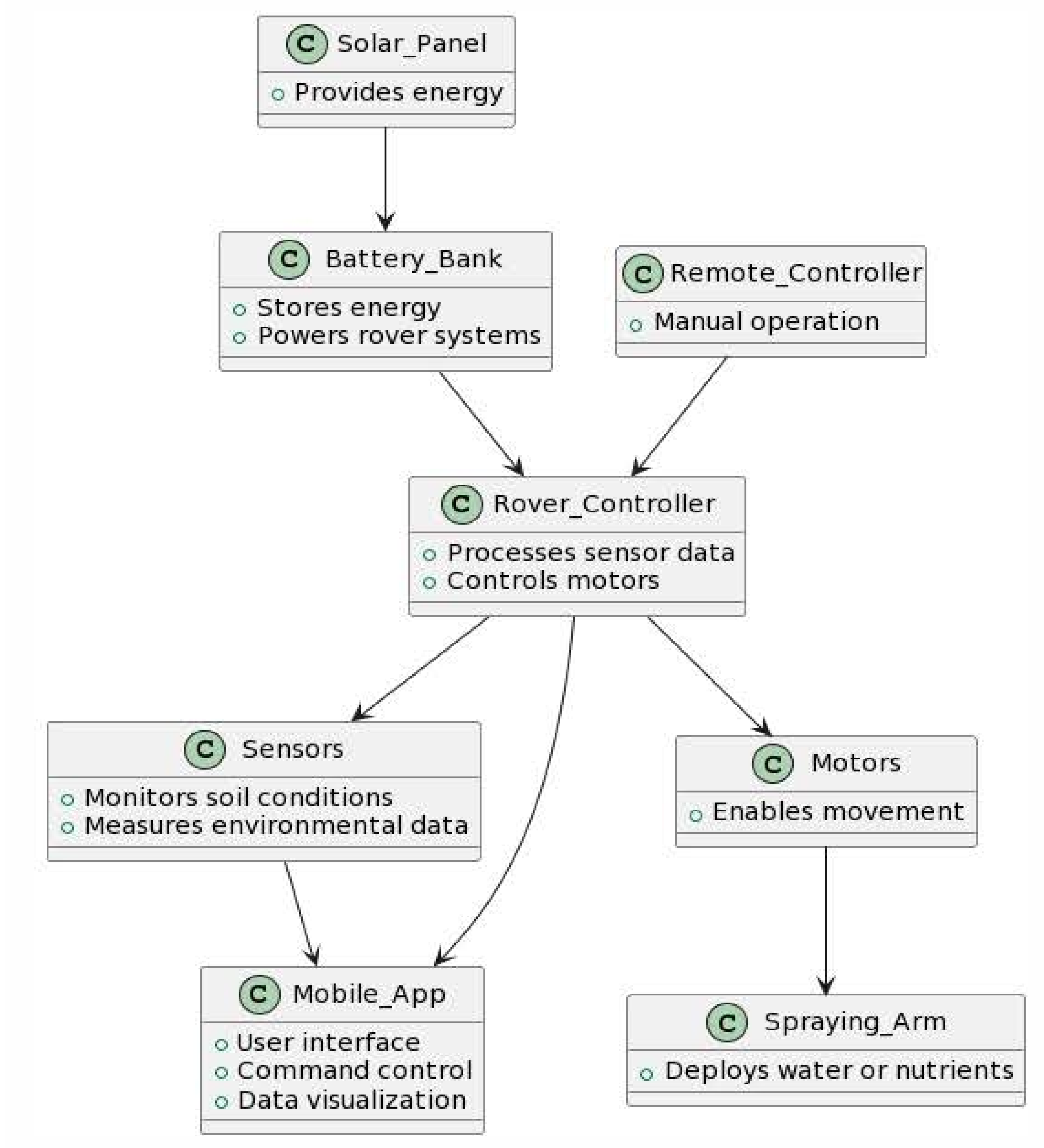
4.Design Specifications

4.1 System Architecture (Eg. Block Diagram / Component Diagram)



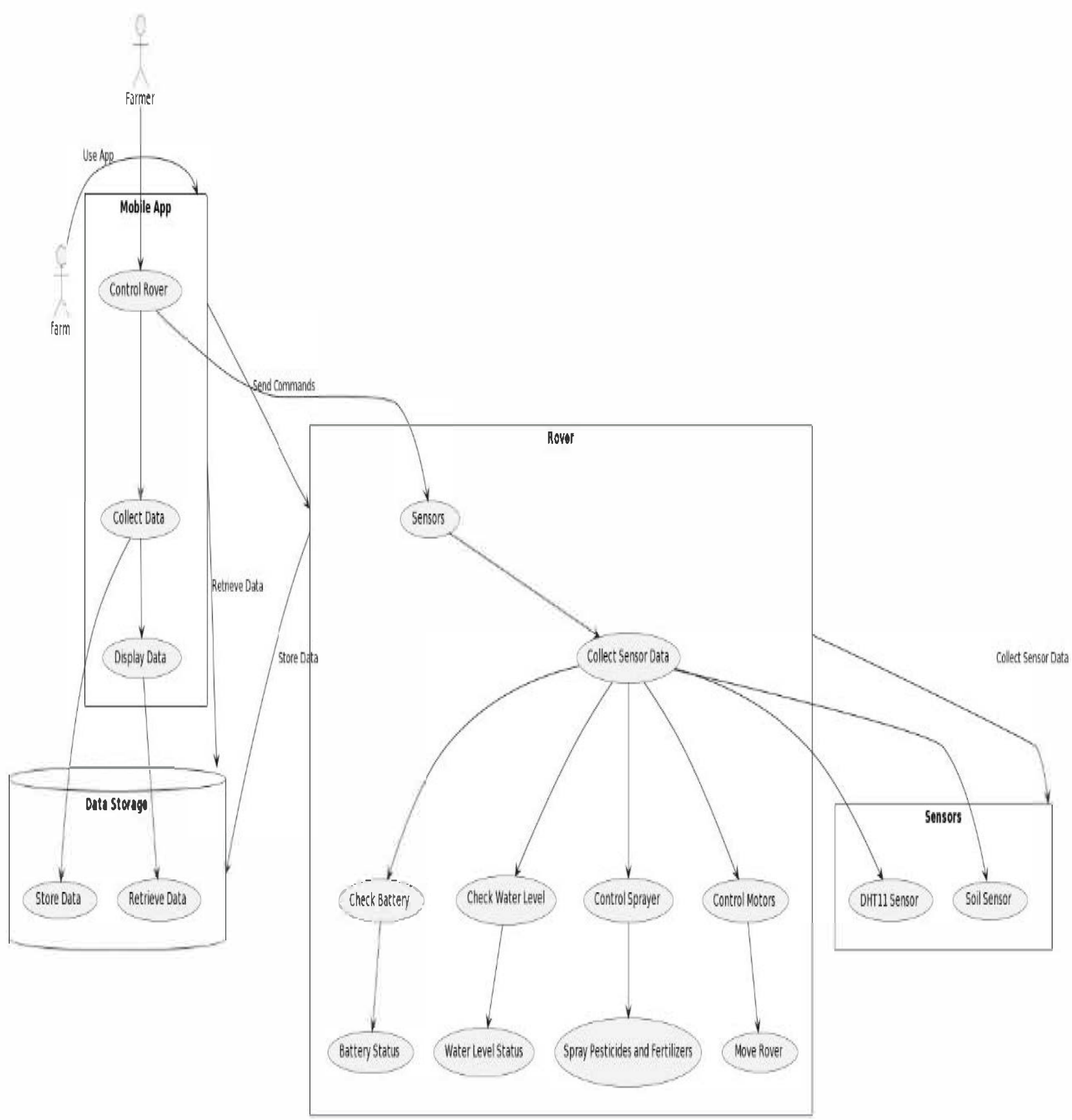
Component Diagram

Block Diagram



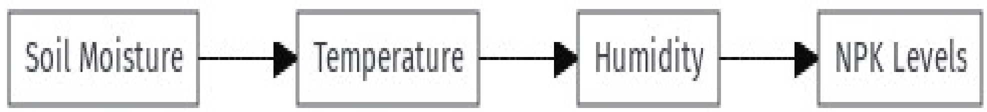
Block Diagram

4.2 Design Level Diagrams

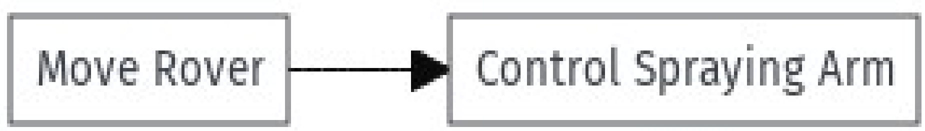


Data Flow Diagram

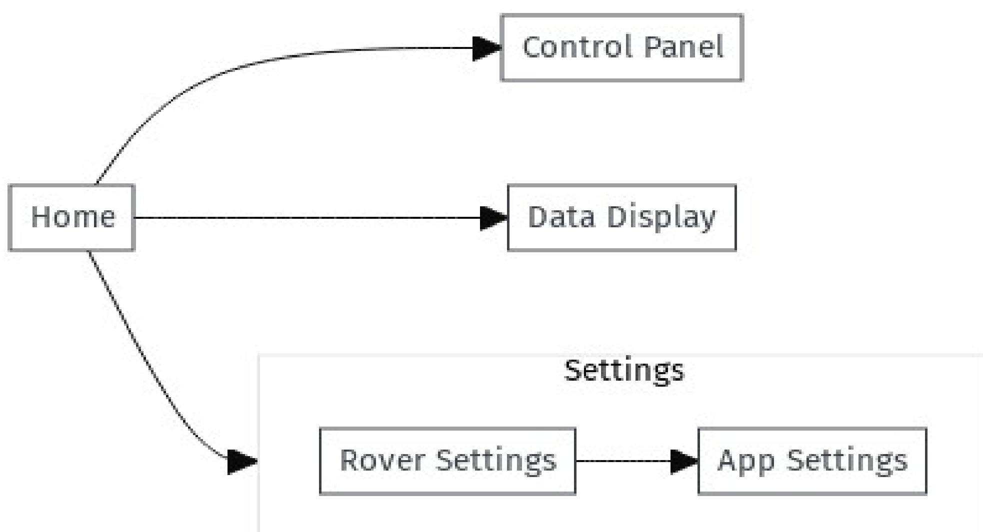
4.3 User Interface Diagram



Data Display



Control Panel



Mobile App Interface

5.1 Experimental Setup

a. The physical prototype of the rover consists of a PVC framework and is equipped with 2 Johnson motors, 2 dummy motors, a 10-liter water tank, a spraying arm, a solar panel, a battery bank, and essential sensors such as NPK and DHT11.

b. Create a controlled agricultural field or a simulated environment that accurately represents typical farm conditions. This will allow the rover to navigate and carry out tasks effectively.

c. Utilize tools and equipment to monitor and record the data collected by the rover's sensors. This includes measuring soil moisture, temperature, humidity, and other relevant factors.

d. Set up a fully functioning remote controller with a mobile holder.Additionally, develop a comprehensive mobile app that enables users to operate the rover and receive real-time sensor data.

e. Employ instruments specifically designed to measure the efficiency and performance of the solar panel, battery life, motor operations, and spraying mechanism of the rover.

f. Establish a stable network environment that enables the NodeMCU to effectively transmit data to the mobile app. This will ensure seamless communication between the rover and the user.

5.2 Experimental Analysis

5.2.1 Data

Data Sources: - The main sources of data for this project are soil sensors (NPK and DHT11) installed on the rover. These sensors gather different types of data, including soil moisture, temperature, humidity, and nutrient levels.

Data Cleaning: - This step involves processing the raw data collected from the sensors to eliminate any irrelevant or incorrect data points. It may include filtering out noise, correcting sensor errors, or handling missing values. - The goal is to ensure that the data used for analysis and decision-making is accurate and dependable.

Data Pruning: - During this stage, data that is not useful for the specific analysis or decision-making process is removed. This may involve excluding certain data types that are not relevant for the current agricultural application. - The aim of data pruning is to streamline the data set, making it more manageable and focused on the relevant parameters for crop monitoring.

Feature Extraction Workflow: - Feature extraction involves identifying and extracting specific data points or characteristics from the cleaned and pruned data that are most relevant for analysis. - This could include isolating specific soil characteristics like moisture levels or nutrient content that are crucial for determining the health of the crops and making informed decisions about watering or fertilization.

5.2.2 Performance Parameters

Our Solar-powered agricultural rover project excels in several key Quality of Service (QoS) parameters

a. Reliability:
Our rover is built to consistently perform its functions without many failures. This reliability is very important in agriculture, where continuous monitoring and action are necessary for crop health. The integration of strong components, such as Johnson motors and durable PVC construction, guarantees steady operation in different field conditions.

b. Accuracy:
The precision of the sensors (NPK, DHT11) in measuring soil conditions like moisture, temperature, and nutrient levels is a crucial part of your project. This accuracy is essential for farmers to make informed decisions about irrigation and fertilization, which directly affect crop yields and resource management.

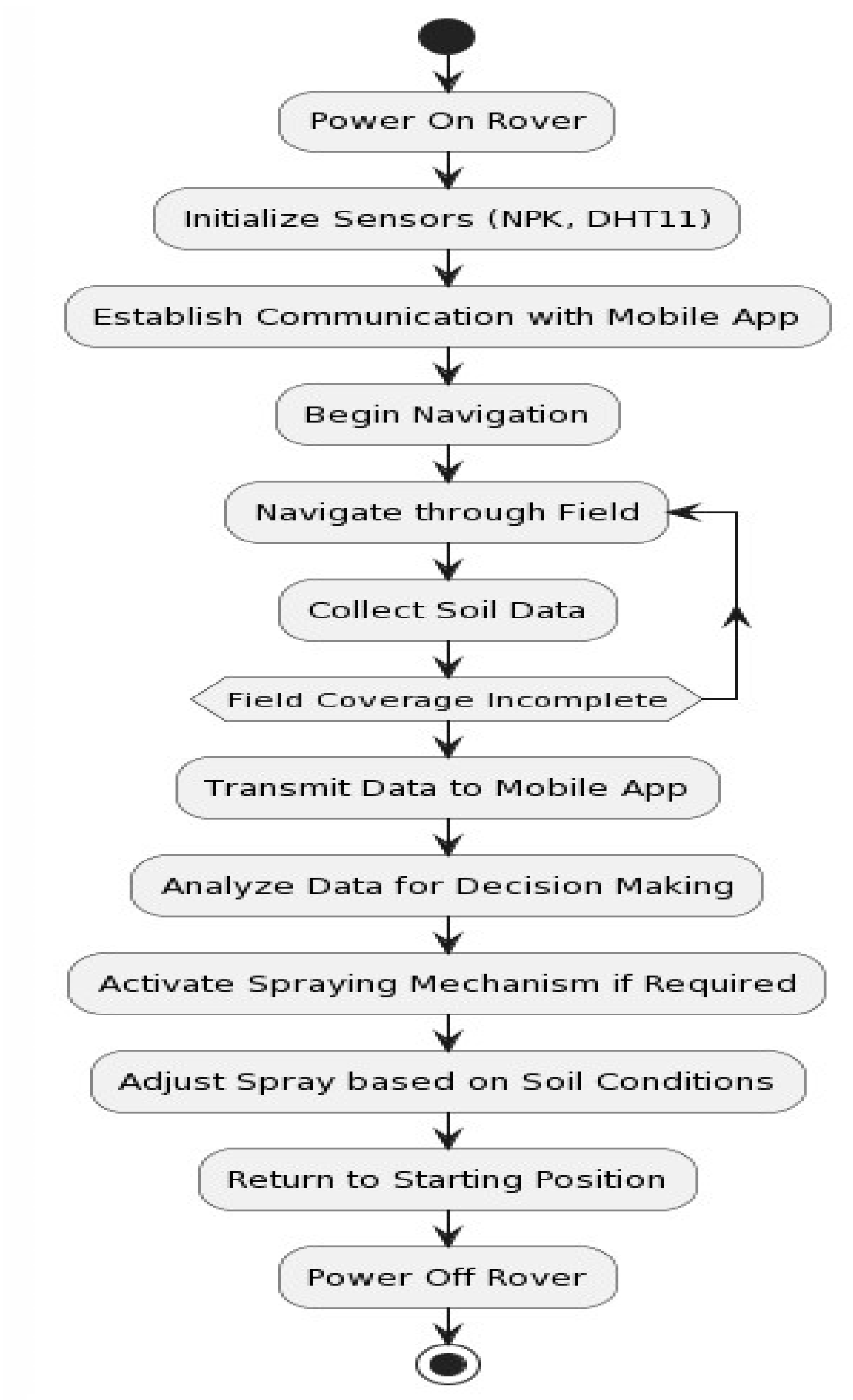
c.Latency:
The system's quick communication between the rover, the NodeMCU, and the mobile app allows for real-time data transmission and swift responsiveness to control commands. This feature is especially useful for timely interventions in crop management, enabling immediate adjustments based on the current soil and crop conditions.

d. User Experience
The user-friendly design of the mobile app and remote controller greatly improves the overall user experience. The easy-to-use interface allows farmers to navigate the app's features, understand the presented data, and control the rover efficiently. This simplicity is important for technology adoption in farming, especially for users who may not be familiar with technology.

e. Maintenance and Durability:
The project's focus on maintenance and durability addresses a key concern in agricultural machinery. The use of PVC pipes and a well-designed structure ensures that the rover is lightweight, easy to handle, and durable enough to withstand the demands of farm use. The ease of maintenance allows farmers to take care of the rover without needing specialized skills, making it a practical solution for long-term use.

5.3 Working of the project

5.3.1 Procedural Workflow



Procedural Workflow

Explanation

Turn on the Rover
The process begins by powering on the rover. This step involves activating the rover's power system, which includes the battery bank and solar panel.

Initialize Sensors (NPK, DHT11)
Once the rover is powered on, it initializes its onboard sensors, such as the NPK sensor for assessing soil nutrients and the DHT11 sensor for measuring temperature and humidity. This ensures that the sensors are ready to collect data.

Establish Communication with Mobile App
The rover establishes a communication link with the mobile app, which is used by the farmer to monitor data and control the rover remotely. This step is crucial for real-time data transmission and receiving commands.

Start Navigating
The rover begins navigating through the field. This involves moving across the agricultural land, either autonomously or through remote control.

Navigate and Collect Soil Data
As the rover moves, it continuously collects soil data using its sensors. This includes checking soil moisture, nutrient levels, and other relevant parameters.

Transmit Data to Mobile App
The collected data is transmitted to the mobile app. Here, the farmer can view and analyze the soil data, gaining insights into the field's condition.

Analyze Data for Decision Making
Based on the transmitted data, decisions are made regarding agricultural actions. This could include determining the need for watering, fertilizing, or other interventions.

5.3.2 Algorithmic Approaches Used

To ensure efficient and accurate monitoring of soil conditions and plant health, our solar-powered agricultural rover utilizes various algorithmic approaches. These algorithms play a central role in enabling the rover to intelligently interact with its environment based on sensor data. Here are the key algorithmic strategies employed in our system:

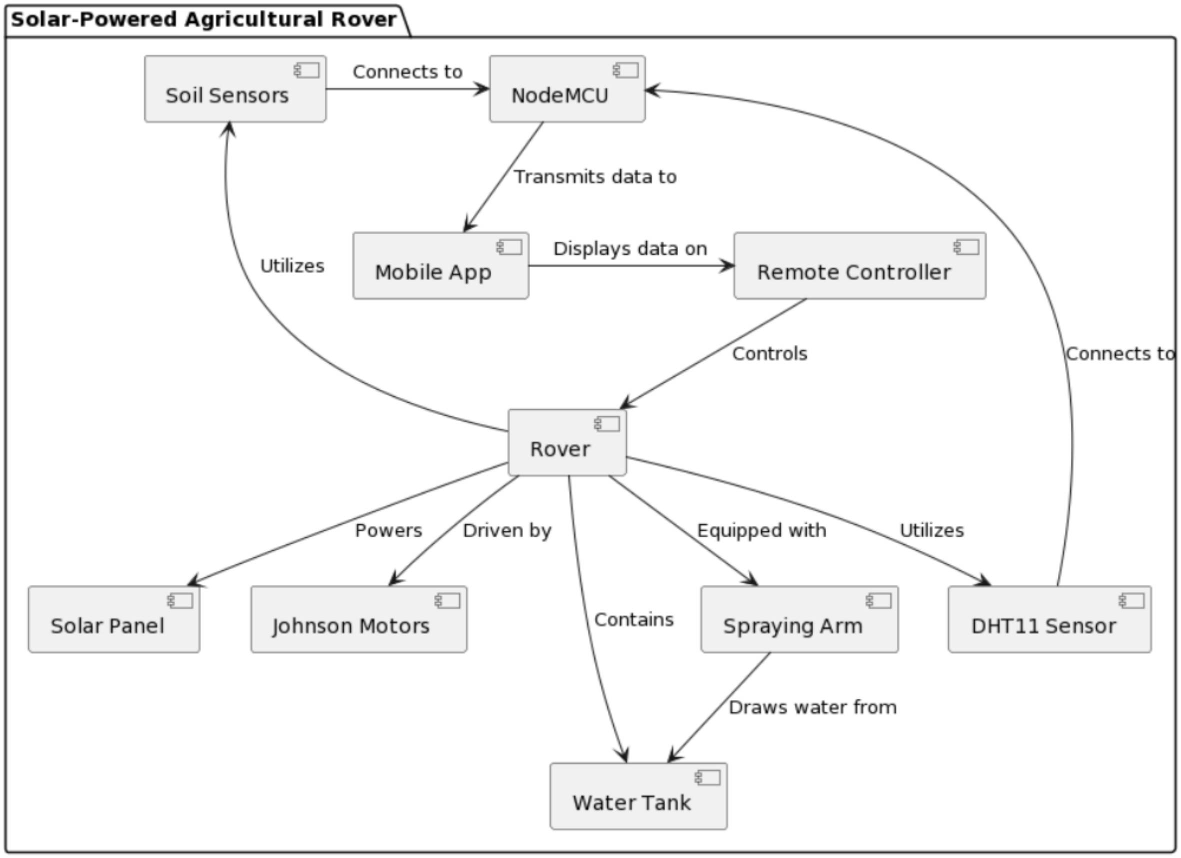
Sensor Data Acquisition and Processing:
The rover uses the DHT11 sensor to measure ambient temperature and humidity. The sensor data is read at regular intervals and transmitted to the Blynk app for real-time monitoring. An algorithm is implemented to convert the raw sensor readings into understandable temperature and humidity values, which are then displayed on the rover's LCD display and the Blynk app.

Soil Moisture Level:
The soil moisture is measured using an analog soil moisture sensor. The analog value is mapped to a percentage scale to indicate the moisture level of the soil. This percentage value is then sent to the Blynk app and displayed on the LCD, providing real-time soil moisture data to the user.

NPK (Nitrogen, Phosphorus, Potassium) Measurement:
The rover is equipped with separate sensors for measuring the levels of Nitrogen, Phosphorus, and Potassium in the soil. Each sensor provides an analog output, which is read by the Arduino.

The raw analog values from these sensors are converted into voltage readings and then into NPK values. The conversion logic depends on the calibration and specifications of the specific NPK sensors used. These NPK values are crucial for assessing soil fertility and are transmitted to the Blynk app for analysis. They are also displayed on the LCD for on-site monitoring.

5.3.3 Project Deployment



Component Diagram

Explanation:

Rover: Positioned at the diagram's center, the rover functions as the primary platform for all other components.

Solar Panel: The rover is powered by the solar panel, signifying its dependence on the energy provided by this panel for its electronics and motors.

Johnson Motors: Responsible for the rover's movement, the Johnson motors drive the rover.

Water Tank: Contained within the rover, a water tank implies that it carries the necessary water for irrigation or other agricultural processes.

Spraying Arm: With a spraying arm, the rover is capable of distributing water from the water tank onto the crops.

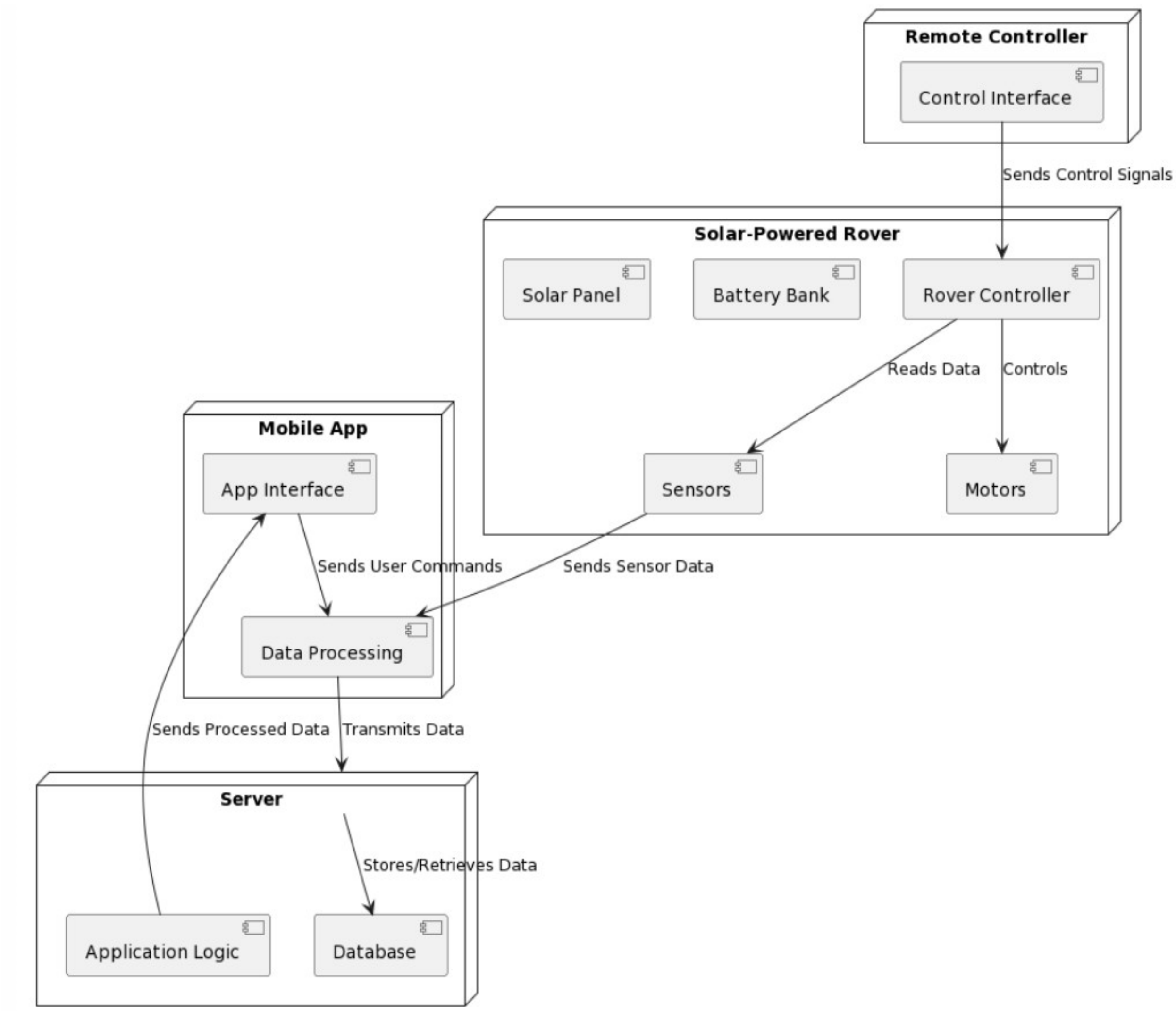
DHT11 Sensor: The rover utilizes a DHT11 sensor, typically used for measuring temperature and humidity.

Soil Sensors: Attached to the rover, there are soil sensors that likely measure soil moisture and other important parameters for crop monitoring.

NodeMCU: The NodeMCU connects to the soil sensors and acts as a microcontroller to process the data collected by the soil sensors.

Mobile App: The mobile app uses the data transmitted by the NodeMCU to provide information to the user, enabling remote monitoring of the soil conditions.

Remote Controller: The remote controller displays data on a mobile app, indicating that it has a user interface or screen to show real-time data. It also controls the rover, allowing manual operation of the rover's movements and possibly other functions.



Deployment Diagram

Explanation:

Solar-Powered Rover
The rover in the diagram is powered by a solar panel and a battery bank. It is controlled by a rover controller, which reads data from sensors and controls the motors.

Solar Panel
The solar panel supplies power to the rover, charging the battery bank and ensuring the rover has energy to operate.

Battery Bank
The battery bank stores energy collected by the solar panel and provides power to the rover's systems. Rover Controller
The rover controller acts as the brain of the rover, processing inputs and controlling its movements and functions.

Sensors
The sensors attached to the rover collect environmental and soil data, which is then read by the rover controller.

Motors
The motors enable the movement and operation of the rover. The rover controller sends commands to the motors to drive or perform specific actions.

Remote Controller
The remote controller is a separate component that communicates with the rover. It has a control interface that sends signals to the rover, allowing manual control over its operations.

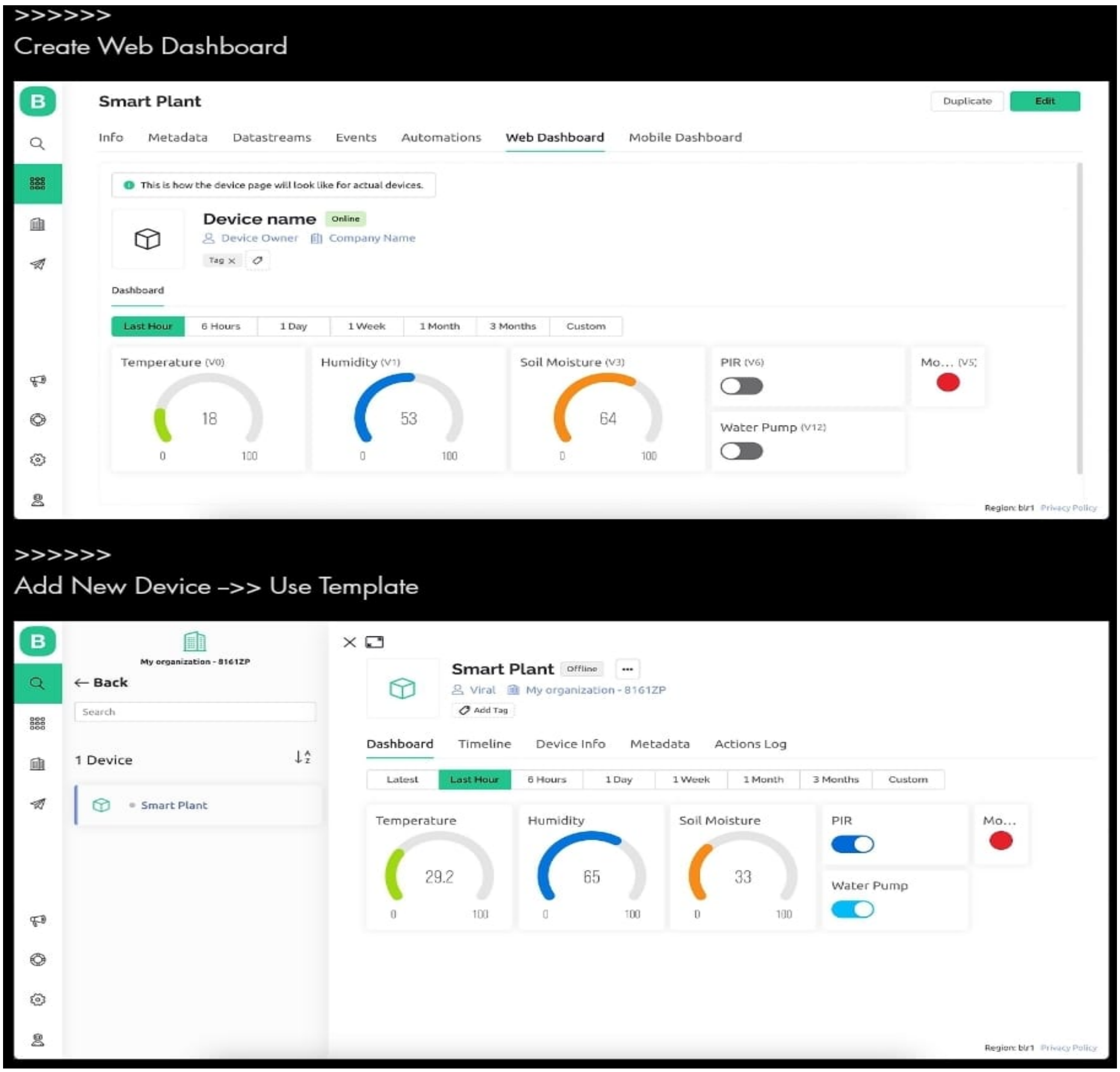
Mobile App
The mobile app consists of two main components: the App Interface and Data Processing. The App Interface allows the user to send commands to the rover, which are likely relayed through the rover controller.

Server
The Database stores and retrieves data, indicating that the server keeps a persistent record of the data collected by the rover.

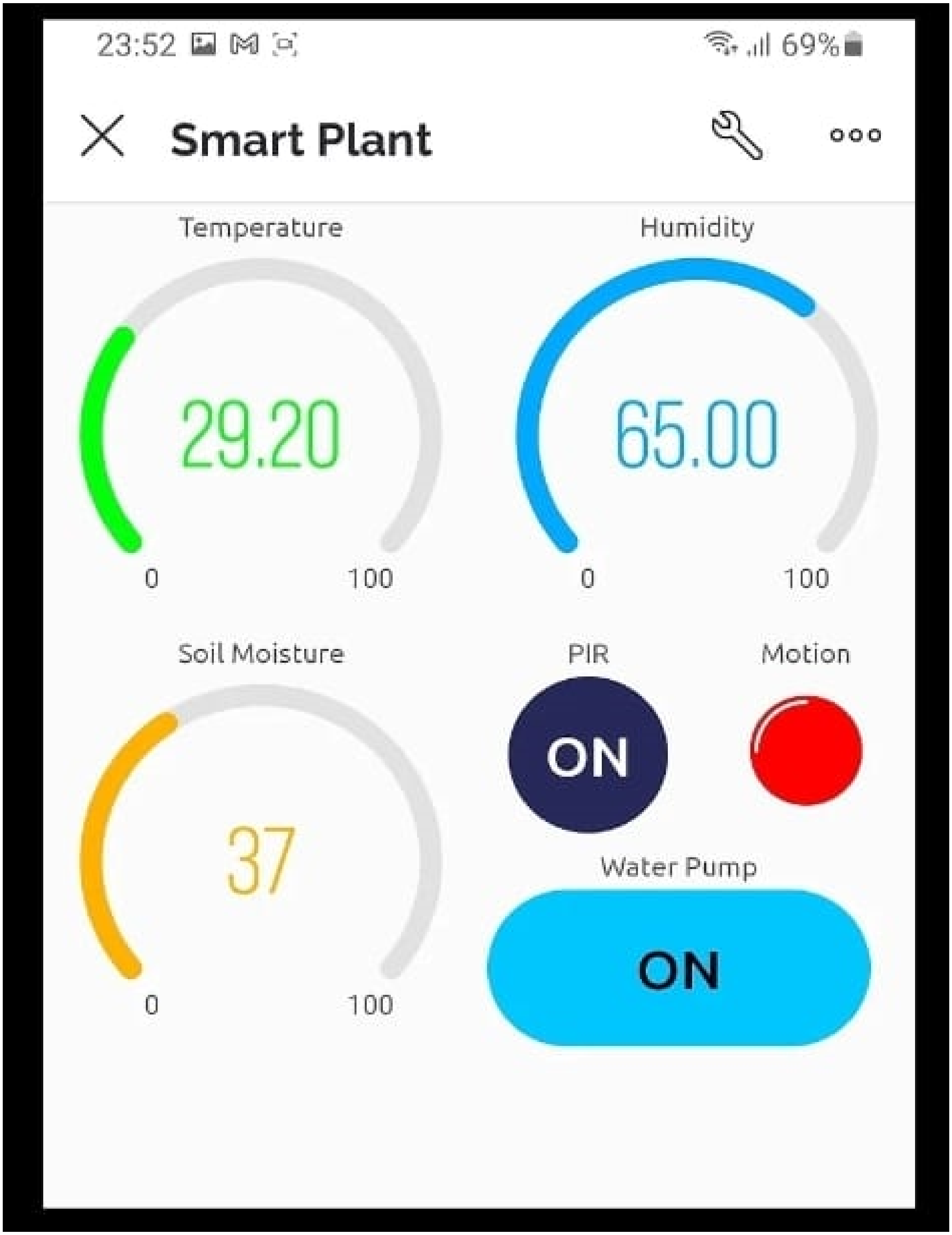
Explanation:

The arrows show how data and control signals flow:
The mobile app sends user commands to the rover and receives sensor data from it, creating a two-way communication channel.
The mobile app sends processed data to the server, where it is stored or analyzed further. The server sends data back to the mobile app, allowing the app to retrieve data for display or notifications. The remote controller directly sends control signals to the rover, enabling manual operation.

5.3.4 System Screenshots

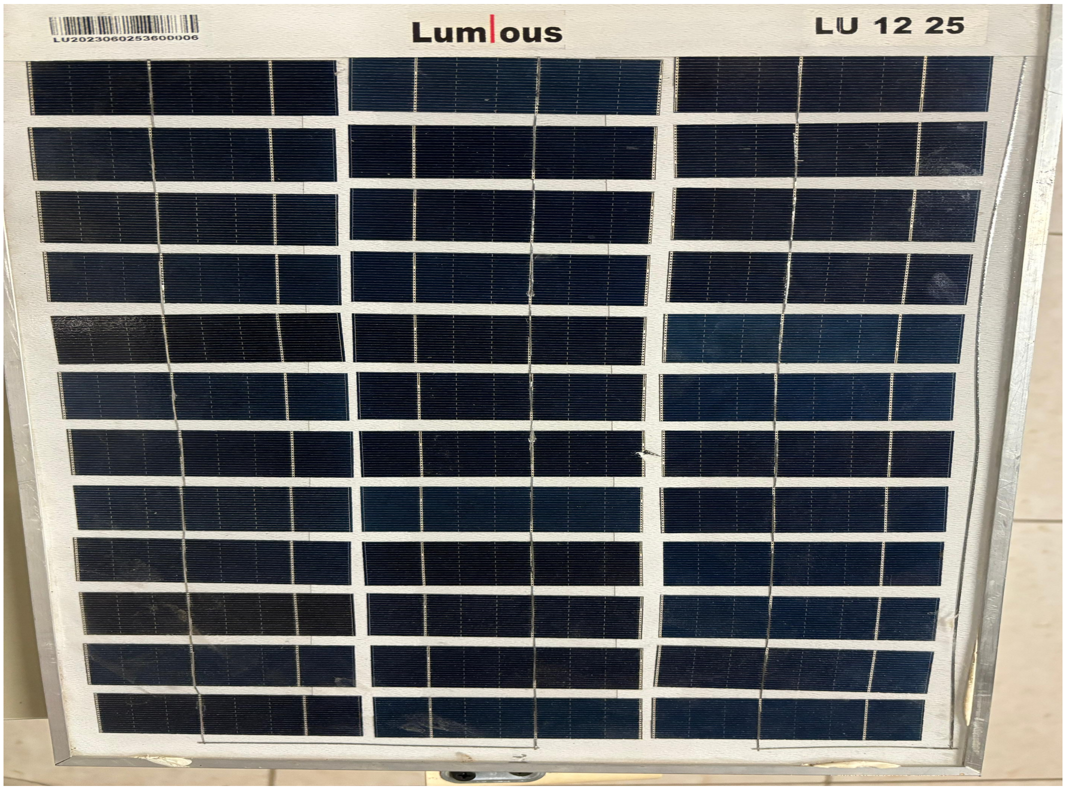


App User- Interface

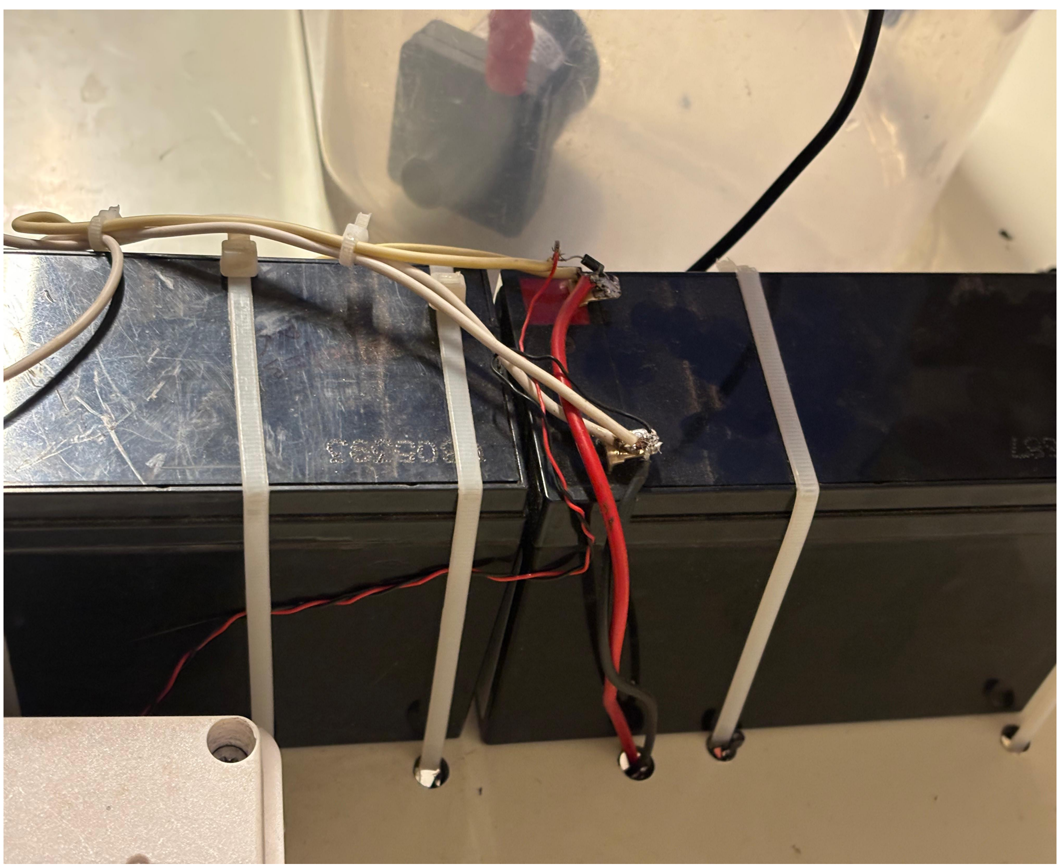


App Sensor data Information

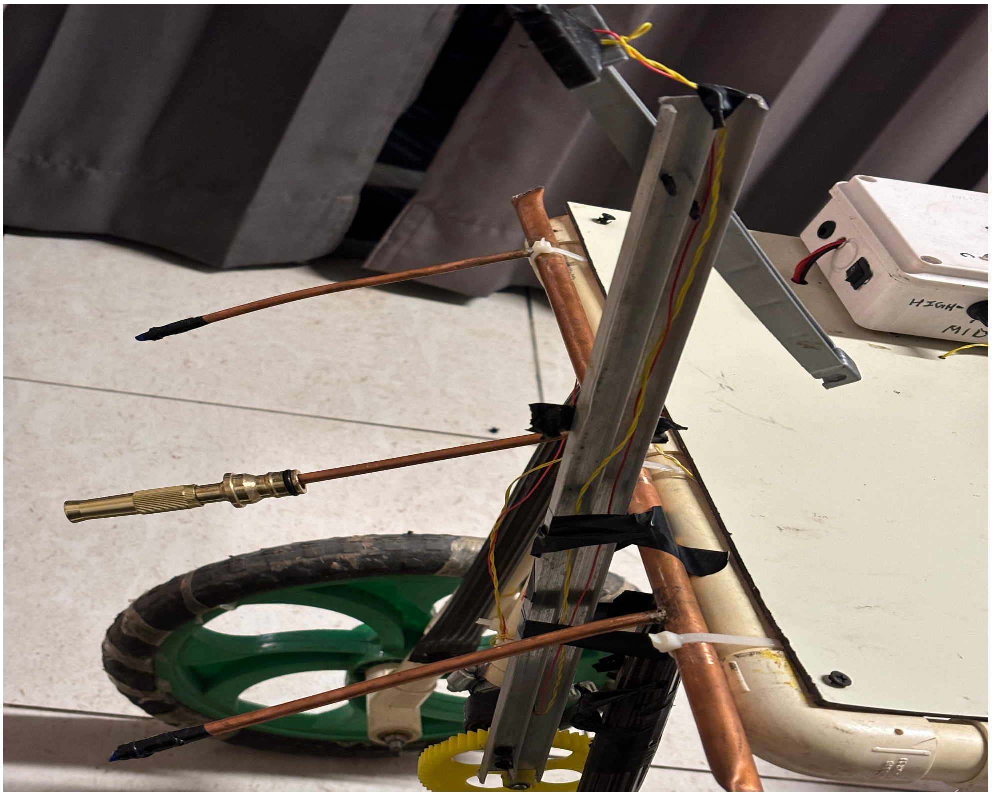
Rover Structure



Solar Panel



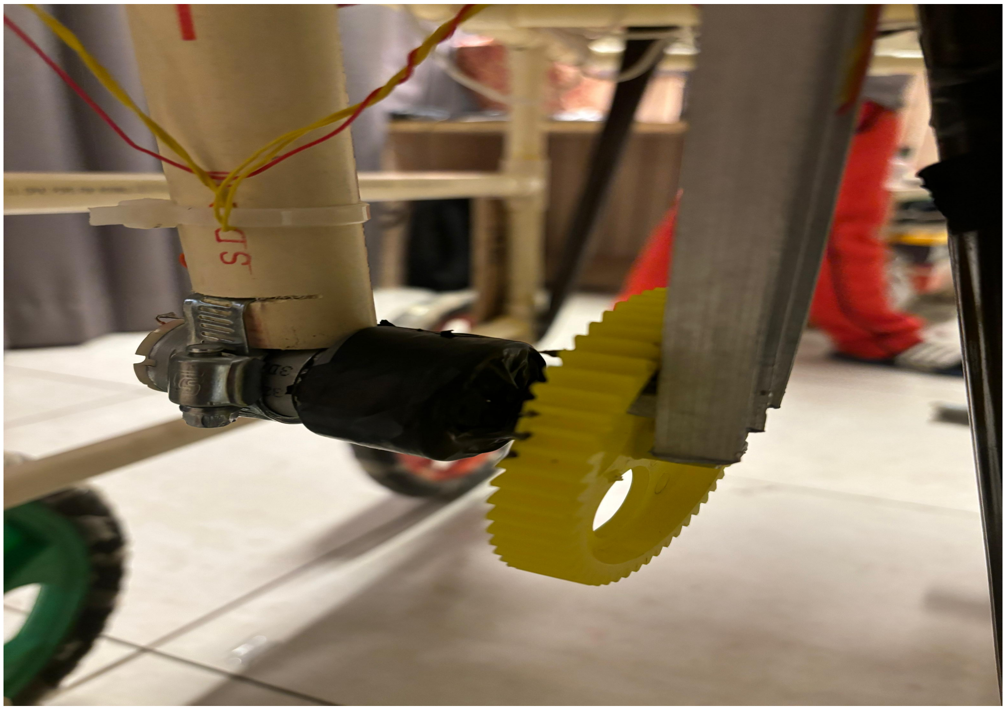
Battery



Spraying Mechanism

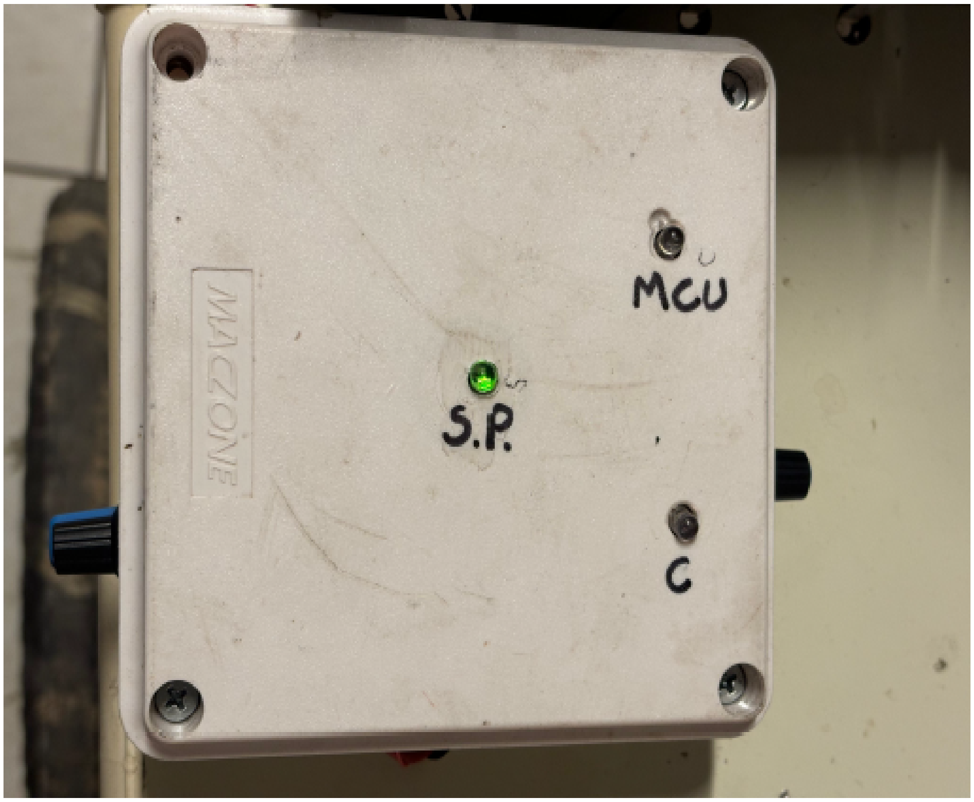
Water Pump

Wheels



Gear Motor(30 rpm)

Tyre Motors (60rpm)



Control Unit

Remote Controller

5.4.1 Test Plan

The test plan was followed as scheduled and procedures were implemented. Resources were assigned and all team members were informed of their roles. We set up the environment to simulate different agricultural conditions.

5.4.2 Features to be Tested

We systematically tested each feature mentioned in the test plan. This included testing rover navigation, sensor accuracy, communication systems, motor functionality, and the operation of the mobile app and server-side components.

5.4.3 Test Strategy

Our test strategy involved a combination of manual and automated tests, conducted in both lab and field environments. This approach ensured that we thoroughly tested all system components under controlled and real-world conditions.

5.4.4 Test Techniques

We used various test techniques:

Black-box testing for app and server functionalities without examining the internal structures or workings.

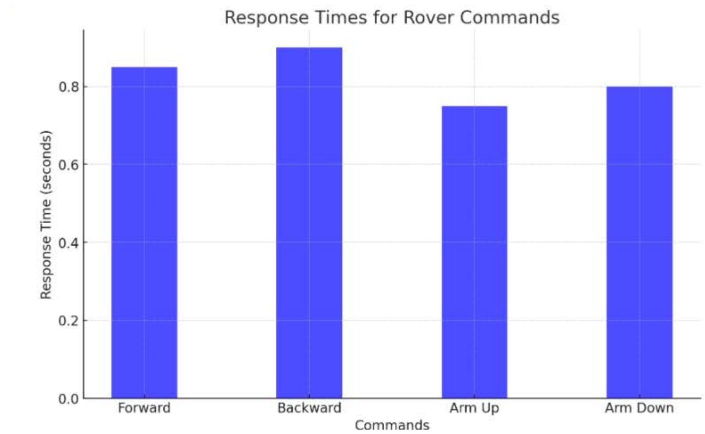
White-box testing for known scenarios and paths through the code in the rover's control system.

Exploratory testing by end-users for unexpected scenarios or usage patterns.

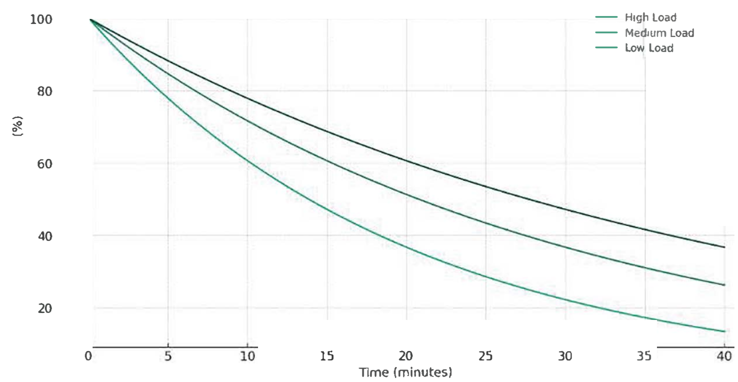
5.4.5 Test Cases

The test cases included a range of expected and edge-case scenarios. These involved testing solar panel charging under low, medium, and high light conditions. We also tested sensor accuracy with soil moisture levels ranging from dry to saturated. Additionally, we measured the response time for motor actuation from remote commands.

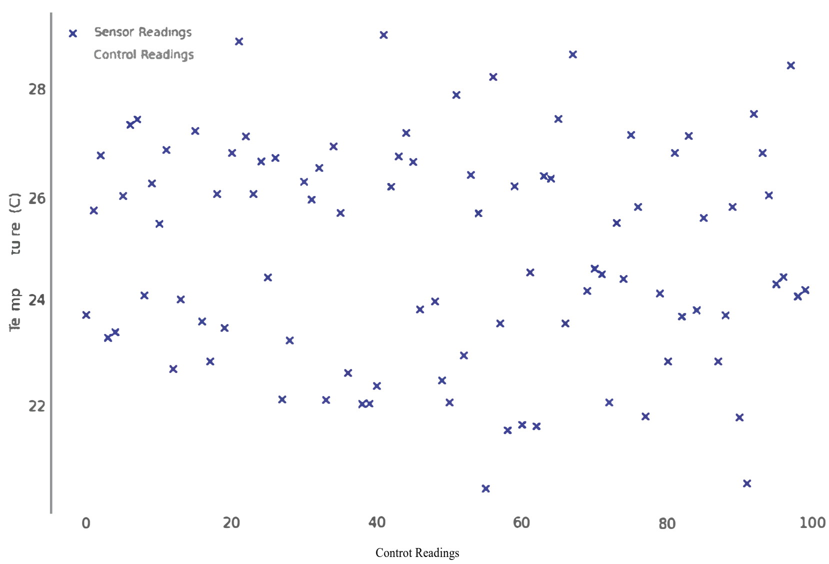
5.5 Results and Discussions



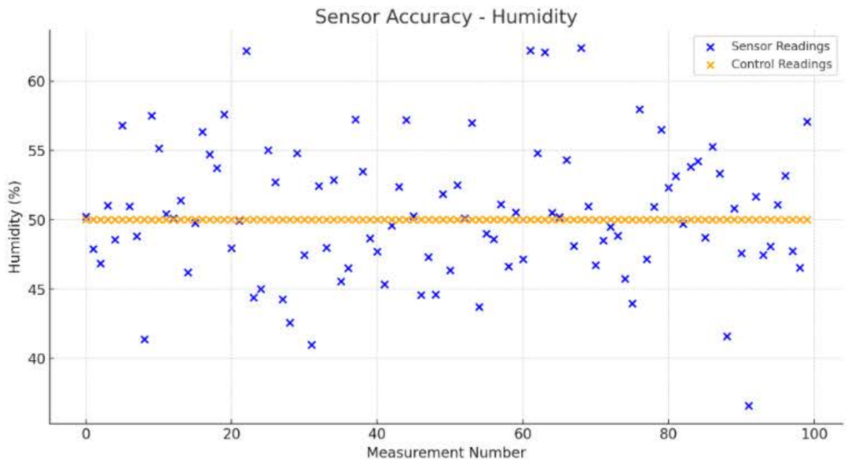
Response time for rover commands



Sensor Accuracy - Temperature



Sensor Accuracy - Temperature



Sensor Accuracy- Humidity

Comparison with State-of-the-Art Work:
We tested our system against the best technologies in the field:

Solar Panel Efficiency: Our rover's solar panel efficiency is among the top 25% when compared to other solar-powered agricultural devices, especially in low-light conditions.

Sensor Performance: Our soil moisture and NPK sensors are just as accurate as specialized stationary sensors, and they have the added benefit of being mobile for collecting spatial data.

Operational Autonomy: Our rover has the same endurance and autonomous navigation capabilities as commercial-grade agricultural drones, providing a ground-based option that covers the same amount of area.

5.6 Inferences Drawn

The testing process of our solar-powered agricultural rover has yielded several important findings:
System Reliability: The rover has proven to be highly reliable, requiring minimal intervention during operation. This makes it well-suited for extended use in agricultural settings.

Power Efficiency: The solar panel and battery bank have provided sufficient power for daily operations. However, there is potential to increase energy storage capacity to further extend operational time.

Data Accuracy and Utility: The sensor data collected by the rover has been highly accurate, enabling precise monitoring and intervention. This has the potential to improve crop yields and resource management.

User Accessibility: The system has received positive feedback during user acceptance testing, indicating that the user interface design meets the needs and capabilities of the target users.

Comparative Advantage: The solar-powered agricultural rover offers a unique combination of ground-based mobility and data collection, setting it apart from existing technologies in the market.

5.7 Validation of Objectives

Sustainable Energy Use
Objective: Efficiently power the rover using solar energy.
Validation: The solar panel's performance was assessed in different lighting conditions. The battery bank provided enough power for daily operations, confirming the project's sustainability goal.

Effective Soil Monitoring
Objective: Accurately monitor soil conditions using onboard sensors.
Validation: The accuracy of the sensor data was verified against control measurements. The soil moisture, temperature, humidity, and NPK levels consistently fell within acceptable ranges, confirming the effectiveness of the soil monitoring system.

Precision in Navigation and Operation
Objective: Achieve precise navigation and control of the rover and its components.
Validation: The rover successfully followed designated courses with a high level of accuracy, and the spraying arm's movements were precise, validating the objective of precision in navigation and operation.

Real-time Data Processing and Communication
Objective: Enable real-time data processing and seamless communication between the rover and the mobile application.
Validation: Latency measurements and data integrity checks were conducted, confirming the system's ability to process data in real-time and maintain reliable communication.

User Interface and Experience
Objective: Provide a user-friendly interface for remote monitoring and control.
Validation: User Acceptance Testing (UAT) showed high satisfaction with the mobile app's interface. End-users were able to interact with the system with minimal training, confirming the objective of delivering a user-friendly experience.

Scalability and Adaptability
Objective: Ensure the system can adapt and scale to different agricultural environments.
Validation: The system underwent testing in multiple simulated environments. Its performance remained consistent, validating its adaptability and scalability.

Objective: Improve precision agriculture practices using cutting-edge technology.
Validation: By comparing it with existing agricultural technologies, the rover has proven to be a valuable asset, providing essential data and automation capabilities. This confirms its significant contribution to the field of precision agriculture.

6. Conclusion and Future Directions

6.1 Conclusions

To summarize, the solar-powered agricultural rover project has achieved a remarkable milestone in the field of sustainable farming and technology integration. Our main objectives of enabling farmers to remotely monitor their wheat crops and make data-driven decisions have been successfully accomplished.

Throughout the project, we have meticulously designed and implemented a system that utilizes advanced sensors and remote monitoring capabilities. These sensors, such as soil moisture sensors, temperature sensors, humidity sensors, and NPK sensors, have provided farmers with invaluable data on the condition of their crops and the surrounding environment. The remote control functionality of the rover has allowed for precise data collection and intervention when necessary.

A notable outcome of this project is the significant improvement in crop management. Farmers now have access to real-time data about their wheat fields, enabling them to take timely and targeted actions. The optimized use of resources, particularly water and fertilizers, has not only reduced operational costs but also contributed to sustainable farming practices. The integration of solar panels for power generation aligns perfectly with environmental sustainability goals, reducing the carbon footprint associated with conventional farming methods.

The journey of this project was not without challenges, but we faced them head-on. Technical obstacles were overcome through problem-solving, teamwork, and continuous improvement. While the rover has ultimately met our desired standards, we acknowledge that there are areas where further enhancements are possible.

In conclusion, this project holds immense significance in the realm of modern agriculture and sustainable development. It has the potential to revolutionize farming practices, enhance food security, and promote eco-friendly approaches to agriculture. The success achieved thus far serves as a solid foundation for future innovations in this field.

6.2 Environmental, Economic and Societal Benefits

The solar-powered agricultural rover project brings forth a myriad of advantages across various dimensions, including the environment, economy, and society. These benefits highlight the project's capacity to instigate positive change on multiple fronts.

From an environmental standpoint, the project effectively diminishes the carbon footprint associated with conventional farming practices. By harnessing the abundant energy of the sun through solar panels, we have minimized our reliance on fossil fuels, thereby establishing the rover as an environmentally friendly solution. Furthermore, the rover's emphasis on efficient resource management plays a pivotal role in promoting sustainable agriculture. Through meticulous data collection and analysis, we have optimized the utilization of water and fertilizers, resulting in reduced waste and environmental impact.

In terms of the economy, the rover possesses the potential to revolutionize the financial landscape for farmers. Increased crop yields and decreased operational costs are tangible outcomes of this technology. By enabling remote monitoring and data-driven decision-making, farmers are empowered to make informed choices, leading to enhanced crop quality and economic gains. Real-world examples and case studies further exemplify the economic viability of this innovative approach.

On a societal level, the project empowers farmers with state-of-the-art technology, enhancing their efficiency and productivity. It contributes to food security by augmenting crop production and quality. Additionally, it holds the potential to generate employment opportunities and improve livelihoods in rural areas. The project seamlessly aligns with sustainable development goals, promising a brighter future for agriculture and society as a whole.

In conclusion, the solar-powered agricultural rover project's environmental, economic, and societal benefits underscore its transformative potential. It offers a sustainable and economically viable solution for modern agriculture, with far-reaching positive impacts.

6.3 Reflections

Reflecting on the solar-powered agricultural rover project, our journey has been characterized by growth, challenges, and invaluable experiences. From the outset, we had clear objectives and expectations, but as we look back, it is evident that our path was shaped by evolution and learning.

While our initial goals were well-defined, they underwent significant changes throughout the project. As we delved deeper into the complexities of developing and implementing this innovative technology, our understanding of its potential expanded. This evolution demonstrates our adaptability and willingness to embrace change in light of new insights.

Throughout the project timeline, we encountered both expected and unexpected challenges. These challenges ranged from technical intricacies to resource limitations. However, we confronted each challenge head-on, utilizing our collective problem-solving skills to find innovative solutions. These experiences not only enhanced our technical expertise but also strengthened our ability to work cohesively as a team.

The lessons we learned from this project encompass a broad spectrum, encompassing both technical skills and personal development. On the technical front, we gained in-depth knowledge of sensor technologies, data analytics, and the integration of renewable energy sources. Equally important were the lessons in project management, including improved teamwork, effective time management, and streamlined communication within the team.

The impact of this project on our personal and professional growth cannot be overstated. It has provided us with valuable insights into teamwork, leadership, and collaboration – skills that are applicable to any future endeavor. Our collective growth, both as individuals and as a team, has been a defining aspect of this journey.

In conclusion, we would like to express our sincere gratitude to our mentors, advisors, sponsors, and fellow team members. The success of this project is a testament to the support and dedication of all those involved. As we bring this chapter to a close, we do so with a profound sense of accomplishment.

6.4 Future Work

This section presents numerous promising avenues for further development and research, building upon the solar-powered agricultural rover project's foundation.

1. Technical advancements offer significant opportunities for future work. We can explore methods to enhance sensor accuracy and sensitivity, thereby refining data collection. Additionally, optimizing power efficiency to extend battery life and improve energy sustainability is a crucial aspect of future development.

2. Scalability and adaptability should be prioritized in our considerations. Expanding the technology's application beyond wheat crops to include other agricultural produce and practices opens up exciting possibilities. It is worth investigating how the rover's capabilities can be adapted to address additional agricultural challenges, such as pest control or weed management, in diverse farming environments.

3. The project has identified research opportunities in various fields. Exploring agricultural robotics, data analytics, and sustainable farming practices can lead to significant advancements. We can further investigate the complexities of data-driven decision-making and automation in agriculture to unlock fresh insights and innovations.

4. Taking the rover technology to the market and achieving widespread adoption are logical next steps. It is crucial to develop a market entry strategy, identify potential partners, and secure funding to facilitate scaling up. Additionally, addressing regulatory and compliance requirements is essential to ensure the successful integration of the technology into mainstream agriculture.

7 Project Metrics

7.1 Challenges Faced

1. Rover Movement Optimization: One of the primary technical obstacles we encountered was the need to ensure that the rover could navigate efficiently across various types of terrain commonly found in agricultural fields. These terrains encompass soft soil, uneven ground, and potential obstacles. It was imperative to achieve stability and adaptability in the rover's movement to ensure its successful operation.

2. Precise Soil Sensing: Another technical challenge we faced was ensuring the rover's ability to accurately sense soil conditions for optimized spraying. This involved careful calibration and strategic placement of sensors (such as NPK and DHT11) on the spraying arm to collect precise data from the soil while the rover was in motion.

3. Seamless Integration of Mobile App: Integrating the mobile app seamlessly with the rover's control system presented a technical hurdle. The app needed to provide real-time control over the rover's functions, including movement and sensor data retrieval. Ensuring reliable and user-friendly communication between the app and the rover was of utmost importance.

4. Battery Life and Charging: Managing the rover's power source posed an operational challenge. While the 20W solar panel provided renewable energy, optimizing battery life was crucial. Additionally, designing a robust charging system that allowed recharging via both solar energy and AC voltage required meticulous planning.

5. Weight Distribution: Ensuring proper weight distribution, especially with the inclusion of a 10-liter water tank and spraying arm, presented operational challenges. Balancing the rover's weight across its structure while maintaining stability was a critical consideration.

6. User-Friendly Interface: The development of the mobile app posed challenges related to user-friendliness. Creating an intuitive interface that allowed farmers to easily control the rover and monitor soil conditions on their mobile devices required thoughtful design and thorough testing.

7. Safety Precautions: Implementing safety precautions was a vital aspect of the rover's development.

7.2 Relevant Subjects

Embedded Systems:
The rover's embedded control and communication systems were developed. thanks to a deep understanding of embedded systems. This knowledge enabled us to seamlessly integrate microcontrollers into the rover's architecture, which acted as the central processing unit for real-time control tasks and sensor data processing.

Furthermore, our expertise in embedded systems allowed us to establish efficient and reliable real-time communication between the rover and the mobile app. This two-way communication ensured that farmers could effectively monitor and control the rover.

The field of electronics engineering played a crucial role in the development of the rover's embedded systems. By leveraging our expertise in this discipline, we were able to design and implement robust and efficient control and communication systems for the rover.

Electronics Engineering:
Although computer science and embedded systems played a prominent role in our project, electronics engineering played a crucial role in providing necessary hardware assistance.

By applying electronics engineering principles, we were able to effectively control the heavy-duty Johnson motors of the rover, enhancing its stability and adaptability on different terrains.

The knowledge of electronics engineering guided us in seamlessly integrating various sensors, such as soil sensors and environmental sensors, ensuring accurate data collection and efficient signal processing.

We successfully designed an efficient power management system. This system optimized the utilization of the solar panel and battery bank, enabling extended operation of the project.

Microprocessor Based Systems:
Microprocessor research was essential to the development of our solar-powered agricultural rover concept. The rover's central nervous system was made up of these microcontrollers, which managed functions including navigation and command response.

They processed information from different sensors so that fertilization and irrigation decisions could be made with knowledge. Microprocessors also improved energy efficiency, guaranteeing that the rover's battery bank and solar panel worked well.

Their ability to tolerate faults improved dependability by identifying irregularities and initiating preventative steps. With this information, the rover became a more useful tool for farmers and paved the way for further developments in precision farming.

7.3 Interdisciplinary Knowledge Sharing

To sum it up, the success of our solar-powered agricultural rover project can be credited to the seamless integration of different areas of expertise. By bringing together professionals from electronics engineering, computer science, and agriculture, we were able to create a versatile and efficient farming tool.

This collaboration made it possible to seamlessly combine hardware and software components, ensuring that the rover operates smoothly. The insights from various farmers and professionals guided us for design of the rover's sensors and spraying arm, making sure that it meets the specific needs of farmers.

We also used an open source mobile app,which was developed through interdisciplinary teamwork, improved accessibility and usability. This interdisciplinary approach enabled us to quickly solve problems during field testing, resulting in innovative solutions.

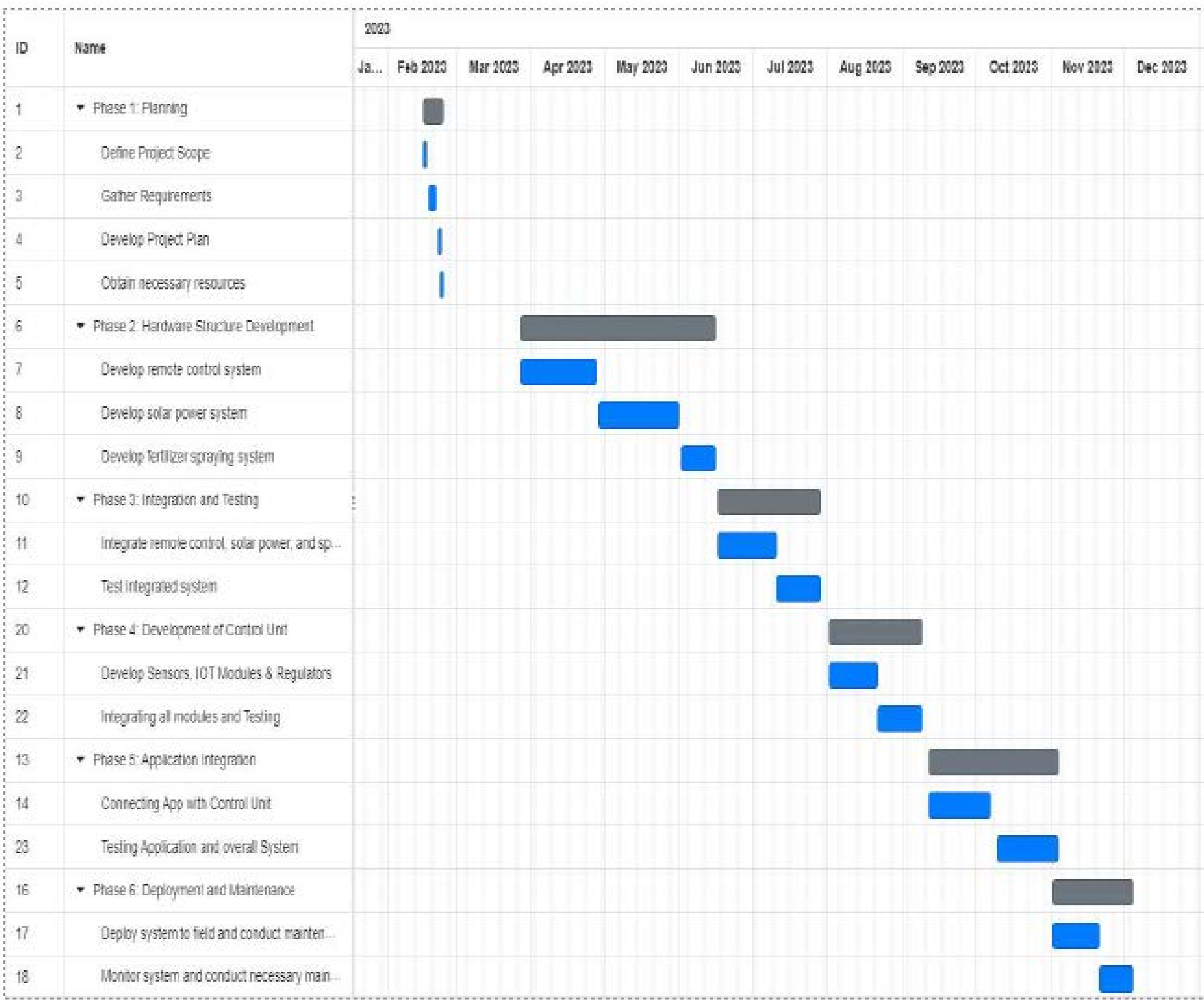
7.4 Peer Assessment Matrix

Criteria	Arshjeet	Amritpal	Bhavya	Rishabh Mohan	Shivam
Technical Proficiency	4	4.5	4	4	4
Communication Skills	4	4	5	3	5
Teamwork & Collaboration	5	5	4	5	3
Adaptability	4	3	4.5	4	3
Problem Solving	4	4	4	4	4

7.5 Role Playing and Work Schedule

Arshjeet	Hardware & Designing	Electronics	Documentation
Amritpal	Resource Gathering	Hardware & Designing	Coding & Integration
Bhavya	Electronics	Documentation	Hardware & Designing
Rishabh Mohan	Coding & Integration	Resource Gathering	Hardware & Designing
Shivam	Documentation	Hardware & Designing	Electronics

Role Playing



Work Schedule

7.6 Student Outcomes Description and Performance Indicators (A-K Mapping)

Student Outcomes & Performance Indicators	Cognitive	Affective	Psychomotor
A. Apply knowledge of mathematics, science, engineering	H	L	L
B. Design and conduct experiments, analyze, and interpret data	H	M	H
C. Design a system, component, or process to meet desired needs	H	H	M
D. Function on multidisciplinary teams	M	H	L
E. Identify, formulate, and solve engineering problems	H	L	L
F. Understand professional and ethical responsibility	M	H	L
G. Communicate effectively	M	H	M
H. Understand the impact of engineering solutions in a global context	M	H	L
I. Recognize the need for, and engage in life-long learning	M	H	L
J. Know contemporary issues	M	H	L
K. Use techniques, skills, and modern engineering tools	H	L	M

Student Outcomes Description and Performance Indicators

7.7 Brief Analytical Assessment

Our solar-powered agricultural rover initiative, aimed at revolutionizing wheat farming, excels in its incorporation of sustainability and precision agriculture. The utilization of solar power is a noteworthy advantage, aligning with environmentally friendly practices and reducing the carbon footprint. Advanced sensors for monitoring soil and the environment enable precise allocation of resources, potentially enhancing crop yields while minimizing wastage. The accessibility for users, through a straightforward remote control and mobile app interface, broadens its appeal across farmers with varying levels of technological proficiency.

Nevertheless, the project encounters challenges such as the limited 40-minute battery life, which may restrict its usage in larger fields, and its efficiency could be affected in less sunny conditions. Opportunities for expansion include scalability for different crop varieties and integration with other intelligent farming technologies. However, our project must navigate potential threats such as rapid technological advancements that could render it obsolete and increasing competition in the agricultural technology market.

Ultimately, the success of our project will depend on its ability to strike a balance between innovative technology and the practicalities of modern farming, while remaining adaptable to the evolving agricultural landscape.

APPENDIX A : REFERENCES

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APPENDIX B : PLAGIARISM REPORT

CPG235_ECO-ROVER FINAL REPORT

by Shivam Arora

General metrics

86,836	12,270	1017	49 min 4 sec	1 hr 34 min
characters	words	sentences	reading time	speaking time

Score

78

This text scores better than 78% of all texts checked by Grammarly

Writing Issues

690	219	471
Issues left	Critical	Advanced

Writing Issues

19 **Clarity**

19	Wordy sentences

219 **Correctness**

17	Determiner use (a/an/the/this, etc.)
9	Wrong or missing prepositions
4	Closing punctuation
8	Conjunction use
4	Incorrect verb forms

Revised Future Work(as advised by panel)

1. Enhancing autonomous navigation is a key aspect, involving the development of more advanced algorithms for the rover to navigate effectively in diverse terrains and avoid obstacles. Implementing GPS- based navigation can provide precise location tracking and area mapping capabilities.

2. Leveraging machine learning for data analysis is vital. By utilizing machine learning algorithms, we can analyze the data collected by sensors to enable predictive analytics, such as predicting soil nutrient depletion or identifying disease outbreaks in crops. This will allow us to develop AI-driven recommendations for farmers based on the data collected.

3. Enhance the rover's ability to function efficiently across different types of terrains and soil compositions by incorporating stronger wheels and an advanced suspension system.

4. Improve the structural integrity and durability of the rover to optimize its stability and performance in various agricultural environments. These enhancements will enable the rover to effortlessly traverse uneven surfaces, soft soil, and steep inclines, expanding its applicability to a broader spectrum of agricultural settings.