A NOVEL REAL-TIME MONITORING AND SEED SPRAYING ROVER USING IOT

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report titled **"A NOVEL REAL-TIME MONITORING AND SEED SPRAYING ROVER USING IOT"** is the bonafide work of **DIVYA C (811721243015), MIRDULA S (811721243028), SWETHA S (811721243056), SRIASHIKA M (811721243304)** who carried out the project under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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DECLARATION

We jointly declare that the project report on **“A NOVEL REAL-TIME MONITORING AND SEED SPRAYING ROVER USING IOT”** is the result of original work done by us and best of our knowledge, similar work has not been submitted to **“ANNA UNIVERSITY CHENNAI”** for the requirement of Degree of **BACHELOR OF TECHNOLOGY**. This project report is submitted on the partial fulfilment of the requirement of the award of Degree of **BACHELOR OF TECHNOLOGY**

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ABSTRACT

Agriculture is the backbone of many economies, yet traditional farming methods often suffer from inefficiencies, labor dependency, and inconsistent monitoring of environmental conditions. To address these challenges, this project proposes a novel real-time monitoring and seed spraying rover using the Internet of Things (IoT) to automate and optimize key agricultural processes. The system integrates various environmental sensors—such as soil moisture, temperature, and humidity sensors—connected to a microcontroller (ESP8266/ESP32) that collects, processes, and transmits data wirelessly to a cloud platform. The rover is capable of navigating farmland and executing seed spraying tasks autonomously or via remote control through a mobile/web-based user interface. Real-time data acquisition allows for adaptive decision-making based on environmental thresholds, enhancing the precision of seed spraying and reducing chemical wastage. The architecture also includes modules for data acquisition, communication, server-side processing, and user interaction. Cloud integration supports data logging and visualization for informed agricultural planning and analysis. The system significantly reduces manual labor, improves spraying accuracy, and supports sustainable farming practices through intelligent automation. It is cost-effective, scalable, and adaptable for various field conditions. By leveraging modern technologies such as IoT, cloud computing, and sensor networks, this project contributes to the advancement of smart agriculture and precision farming.

LIST OF FIGURES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

BMS	-	Battery Management System
GPS	-	Global Positioning System
GSM	-	Global System for Mobile Communications
IoT	-	Internet of Things
LCD	-	Liquid Crystal Display
LDR	-	Light Dependent Resistor
MCU	-	Microcontroller Unit
NFC	-	Near Field Communication
PCB	-	Printed Circuit Board
PLC	-	Programmable Logic Controller
PWM	-	Pulse Width Modulation
RFID	-	Radio Frequency Identification

CHAPTER 1

INTRODUCTION

The system proposes a new plan to put back humans in diverse agricultural operations like detection of the presence of pests, spraying of pesticides, spraying of fertilizers, etc. thereby providing safety to the farmers and accurate agriculture. The evolved system includes plotting a prototype that uses simple cost-effective equipment like microprocessors, solar panels, wireless, different motors and terminal equipment which helps the farmers in different crop field activities. The main feature of this system is Electrostatic spraying. This application is adopted in crop protection to prevent pest infestation, to improve product quality and to maximize yield. It involves a superposition of charges to pesticide spray droplets to attract substrate ions at hidden surfaces. The droplets wraparound effect lowers off-target deposition, increases on-target spray and invariably improves spray efficiency. Electrostatic spraying system works productively at best suitable parameters in union with charging voltages, spraying height arrangement, application pressures, flow rate, travel speed, electrode material, and nozzle orientation. Soil moisture information plays an important role in environmental monitoring, agricultural production and hydrological studies. Particularly, agricultural yield depends on several growing parameters like temperature, humidity, soil moisture and pH of the soil, etc. In this project, we have designed and developed a system for measuring and monitoring soil moisture by interfacing low-cost soil moisture sensor with Internet of Things (IoT), Cloud computing and Mobile computing technologies.

1.1 BACKGROUND

Agriculture plays a significant role in global food security and economic growth, yet it faces numerous challenges such as increasing demand for food, environmental changes, and the need for sustainable farming practices. One of the key areas where technology can support farmers is in optimizing crop protection and enhancing agricultural productivity systems into agriculture.

Electrostatic spraying technology is one such breakthrough that has shown great potential in improving pesticide application efficiency and reducing chemical waste. By charging spray droplets, the technology increases the adhesion of pesticides to crops, thereby ensuring more effective pest control and minimal off-target contamination. Additionally, monitoring environmental factors like soil moisture, temperature, and humidity plays a crucial role in optimizing irrigation and fertilization strategies. The integration of sensors to monitor these parameters can significantly enhance crop management decisions.

This project focuses on the design and development of an agriculture-based seed sprayer system that detects and monitors environmental factors such as temperature, humidity, and soil moisture. The system uses low-cost sensors, IoT, and cloud computing to provide real-time data and support efficient crop management.

1.2 PROBLEM STATEMENT

- Traditional agricultural practices often rely on manual labor and conventional methods for pest control, irrigation, and crop management. These approaches are time-consuming, inefficient, and may result in high chemical usage or improper application of fertilizers and pesticides. Additionally, monitoring environmental parameters like soil moisture, temperature, and humidity manually can be inaccurate and cumbersome, leading to suboptimal crop management.

- The lack of real-time data and efficient application techniques limits farmers' ability to respond quickly to changing conditions, leading to decreased productivity and increased costs. There is a need for a more effective, automated system that not only ensures accurate pest control but also optimizes crop management through real-time environmental monitoring.

- It aims to address these challenges by developing an affordable and efficient agricultural system that integrates electrostatic spraying, environmental monitoring sensors, and IoT technology to improve crop protection, minimize resource wastage, and maximize yield.

1.3 OBJECTIVES

- Develop a Cost-Effective Agricultural System: To design and develop a prototype seed sprayer system that integrates low-cost sensors for measuring temperature, humidity, a nd soil moisture.
- Enhance Pesticide Efficiency: To implement electrostatic spraying technology to improve pesticide application, reduce chemical wastage, and enhance on-target deposition.
- Utilize IoT and Cloud Computing: To interface the sensor system with IoT and cloud computing technologies to provide real-time monitoring, data collection, and analysis that can be accessed through mobile applications.
- Improve Agricultural Productivity: To create a system that supports farmers in optimizing crop management through better pest control and environmental monitoring, ultimately enhancing yield and product qual.

CHAPTER 2

LITERATURE SURVEY

2.1 IOT BASED SEED PLANTING AND WATERING ROVER

G Nagarjuna Reddy, G Maheedhar Reddy, G Balaji, CH Muni Harish

Exploring Mars and other planets aids scientists in their understanding of severe climate swings that have potential to drastically affect the planets. This Automated Rover takes on the role of a human by planting and watering the plants on its own. This paper is focused on automated seed planting and monitoring using Internet of Things (IoT). Rover is a movable device that is powered by ESP8266 Node MCU controlled DC motors. Rover is equipped with a DHT11 sensor and a Wi-Fi module that continuously monitors and uploads data to Thingspeak. This rover is equipped with a plough that can be adjusted, a seed dropper, and automated water pouring equipment. An Arduino Nano can be used to control all of the actions. It estimates the distance between each seed after dropping the seed, so that it can water the seeds automatically after 12 or 24 hours. Depending on availability, the rover uses both DC battery and solar energy to power the entire setup. All the rover's actions are fully automated.

Merits - Achieved 90% accuracy in seed placement and reduced water usage by 35% through precision irrigation.

Demerits - Requires constant internet connectivity for data transmission

2.2 DEVELOPMENT OF IOT CONTROLLED AGRI-ROVER FOR AUTOMATIC SEEDING

Aditya Vishwas Kanade1, Arockia Selvakumar A2*, Dnyanesh Jalamkar3

The field of robotics can be modified with the combination of number of approaches such as, mechanical approach, software technology and electronic control system approach together. In the period of current globalization, scientists are trying to apprise advancements based on robotics which operates and performs tasks very effectively, efficiently and in lesser time. These progressions can be utilized to improve Indian traditional approach of farming. Since in Indian scenario, near about 70% population is reliant on agriculture. So the agricultural field in India should be improved to increase the yield. Agree rover is the best solution to meet the rising demand on quantity and quality of agriculture products and declining labor availability in rural farming areas. The main aim of the designed system is efficient utilization of resources and to reduce a laborious work. The seed sowing operation is performed by the system using servomotor mechanism controlled by ARDUINO controller and robot motion is controlled by Internet of Things (IoT).

Merits - Achieved 88% accuracy in uniform seed spacing and reduced manual labor by 70% through automated row-based navigation without GPS.

Demerits - High initial setup cost for automation Complexity in programming and system maintenance

2.3 IOT BASE SMART AGRICULTURE AND AUTOMATIC SEED SOWING ROBOT

Hemanth Kumar R K1 , Arun kumar2, Balija Yashwanth3, B Karthik4

This paper proposes an innovative approach to revolutionize agriculture through the integration of IOT technology and autonomous robotics. The system aims to optimize agricultural processes by employing a smart IOT network to monitor environmental conditions such as moisture in soil, temperature, and humidity in real-time. Additionally, a custom-designed autonomous robot equipped with seed sowing capabilities is introduced to automate the planting process efficiently. The robot utilizes data from the IOT network to determine optimal planting locations and adjust its operations accordingly. Through this integration, farmers can get higher crop yields, reduce resource wastage, and enhance overall agricultural productivity. The proposed system offers a sustainable solution to address the challenges faced by modern agriculture, paving the way for a more efficient and environmentally friendly farming approach.

Merits - Achieved 85% uniform seed placement accuracy and reduced manual intervention by 60% using timed motor-based seeding

Demerits- High power consumption for sensors and devices.

2.4 SMART AGRICULTRE MONITORING ROVER FOR SMALL-SCALE FARMS IN RURAL AREAS USING IOT

Anjana Menon, R.Prabhakar

Agriculture has been one of the ultimate factors contributing to the survival and development of human civilizations for generations across the globe. Due to extreme climatic changes, destruction of forest cover and industrial advancements the production rates and quality of crops grown in agricultural farms have been drastically affected. This has affected the very livelihood of human beings. Thus, there is a need for a real-time monitoring device to continuously monitor the crops and ensure that it remains healthy until harvest. The system proposed in this paper is based on Internet of Things technology with the Arduino Mega Development board. The system performs monitoring of Weather, Soil Parameters and detects fire, insects or pests surrounding the area. It provides a sprinkler system for spraying water, organic pesticides, and insecticides according to the monitored data analysed by the microcontroller. The system is automated as it is powered by solar energy and all functions and geographic coordinates of each crop are pre-programmed into the microcontroller. This system will also aid in water conservation through controlled irrigation and increases production rate.

Merits - Enhanced crop health monitoring by 75% and improved irrigation efficiency by 40% through real-time soil and environmental data collection.

Demerits- Connectivity and data transmission issues in remote areas .

2.5 IMPLEMENTING SMART AGRICULTURE WITH IOT AND MONITORING PLANT DISEASES WITH REGRESSION ANALYSIS

K. Harish4, S. Asif Alisha5, N. Lenin Rakesh6, D R K Saikanth7

Robots, automation, the Internet of Things (IoT), and its application based on precision agriculture are essential to reduce the burden of peoples in farming. Making this method more effective depends on the addition of machine learning-based leaf disease detection. The farmer may end up saving time and effort, increasing output, and increasing efficiency as a consequence. The usage of multiple electronic sensors and cloud-based services in agriculture may also help with quick processing and accurate measurement of any parameter. A prototype agricultural rover with ploughing, seeding, and separate autonomous irrigation and fertilizer sprinkling systems was developed to ensure appropriate farming. The rover is managed by a smartphone using a Wi-Fi module. The automated irrigation and fertilizer dispensing systems include characteristics that may be shown on an OLED display and a cloud-based IoT analytics service called thing talk. Machine learning-based logistic regression is used with several adjustments to improve the accuracy of the diagnosis of leaf disease.

Merits - Improved crop yield predictions by 80% and optimized resource usage by 30% through IoT-based environmental monitoring.

Demerits- Dependency on internet connectivity for full functionality.

CHAPTER 3

SYSTEM ANALYSIS

3.1 EXISTING SYSTEM

Agriculture in rural India faces challenges due to workforce shortages from migration. To address this, semi-automatic robots have been developed to assist in basic farming tasks. It performs seeding and watering based on seed spacing and soil moisture. It operates within a limited area and follows a user-defined path via GUI. Watering is regulated using a soil moisture sensor placed between plants. This low-cost system shows potential for small-scale farming, research, and home gardening

3.1.1 Components Used

Integrated Development Environment (IDE)

An Integrated Development Environment (IDE) is a software tool used to write, compile, and upload code to the Agri-bot's microcontroller. It helps in programming tasks like controlling motors, sensors, seeding, and watering functions. IDEs also support debugging and real-time monitoring to ensure smooth operation of the robot.

Global Positioning System (GPS)

The Global Positioning System (GPS) enables precise navigation and location tracking for the Agri-bot during field operations. It helps in mapping the land and guiding the bot along predefined paths for accurate seeding and watering. This ensures efficient coverage and minimizes overlap or missed areas.

Global System for Mobile Communication (GSM)

Global System for Mobile Communication (GSM) module is used to enable remote communication. It allows the bot to send updates or alerts to the farmer via SMS. This ensures real-time monitoring and control, even from a distant location.

Graphical User Interface (GUI)

Graphical User Interface (GUI) was designed to provide an intuitive control panel for users. It allows real-time monitoring and manual override of the bot’s operations like movement, seeding, and watering. The GUI enhances user interaction, making the system more accessible and efficient for agricultural tasks.

3.1.2 Drawbacks

- Limited Field Coverage
- Lack of Autonomous Navigation
- Basic Sensing Capabilities.

3.2 PROPOSED SYSTEM

A proposed automatic seeding and watering application system, the Smart Spraying System upgrades a standard sprayer with automation for precise chemical application. It includes a 130L tank, a 1 kW DC motor-driven pump, pressure and flow rate sensors, and two electric on/off valves controlling stainless-steel spray bars. Equipped with wind speed and temperature/humidity sensors, it prevents spraying under unsuitable conditions. The Electronic Control Unit (ECU) enables remote operation via TCP-based communication, while a ROS-based Sprayer Node ensures automatic activation at predefined waypoints. The Human-Machine Interface (HMI), running on a tablet PC, allows non-expert operators to monitor the system, plan missions, define spray treatments, and generate automated reports compliant with European regulations. This system enhances efficiency, reduces chemical waste, and improves safety in challenging agricultural environments like greenhouses and steep terrains.

3.2.1 Components Used

ARDUINO UNO Rev3

The Arduino Uno Rev3, powered by an ATmega328P microcontroller, controls the robot’s movement and spraying system. The user activates the robot via Bluetooth from a mobile phone, allowing it to process ultrasonic sensor data for obstacle avoidance. A servo motor periodically moves the nozzle while the pump sprays pesticides or nutrients. This system ensures automated, efficient, and precise spraying in agricultural applications.

Power Supply Unit

A multi-output power supply is crucial in project development, as different sensors require varying voltages and currents for optimal performance. Using multiple regulated power supplies (RPS) or AC adapters can make the system bulky and inefficient. A single integrated power supply that provides multiple voltage outputs is a more practical and space-saving solution for streamlined operation.

Spray Motor

The spray motor is used to spray pesticide to control insect based on the Arudino unit instruction. Spray Pump DC 4v-9V Spray motor for Arduino based Robotics.

IoT – ESP8266

This is a IoT module, it used to store all data in the cloud. The sensor information, arudino controlling information, water tank information are stored in the cloud using IoT.

3.2.2 Advantages

- Enhanced Precision and Efficiency
- Real time monitoring and control
- Labor and Cost Reduction.

CHAPTER 4
SYSTEM SPECIFICATIONS

4.1 HARDWARE SPECIFICATIONS

- Computer - minimum of 4GB RAM & dual-core processor.
- Stable internet connection.
- Storage

4.2 SOFTWARE SPECIFICATIONS

- Platform: ESP8266/ESP32
- Programming Languages: C/C++,
- Communication Protocols: MQTT, HTTP, Wi-Fi, Zigbee

4.3 SOFTWARE DESCRIPTION

The Arduino software setup involves installing the Arduino IDE, connecting the board via USB, and selecting the correct board in the Tools -> Board menu. Users can create a new project or open an example program like Blink to test functionality. The board is powered through USB or an external source, with a green LED indicator confirming power. Once set up, programs can be compiled and uploaded for execution.

CHAPTER 5

SYSTEM DESIGN

A system architecture is the Agri-bot's integrated system, starting with a sensor unit that gathers environmental and soil data. The data is processed by a microcontroller, which then activates seeding and watering mechanisms. Finally, the system communicates with a remote server or mobile app, allowing for real-time monitoring and control.

5.1 SYSTEM ARCHITETURE

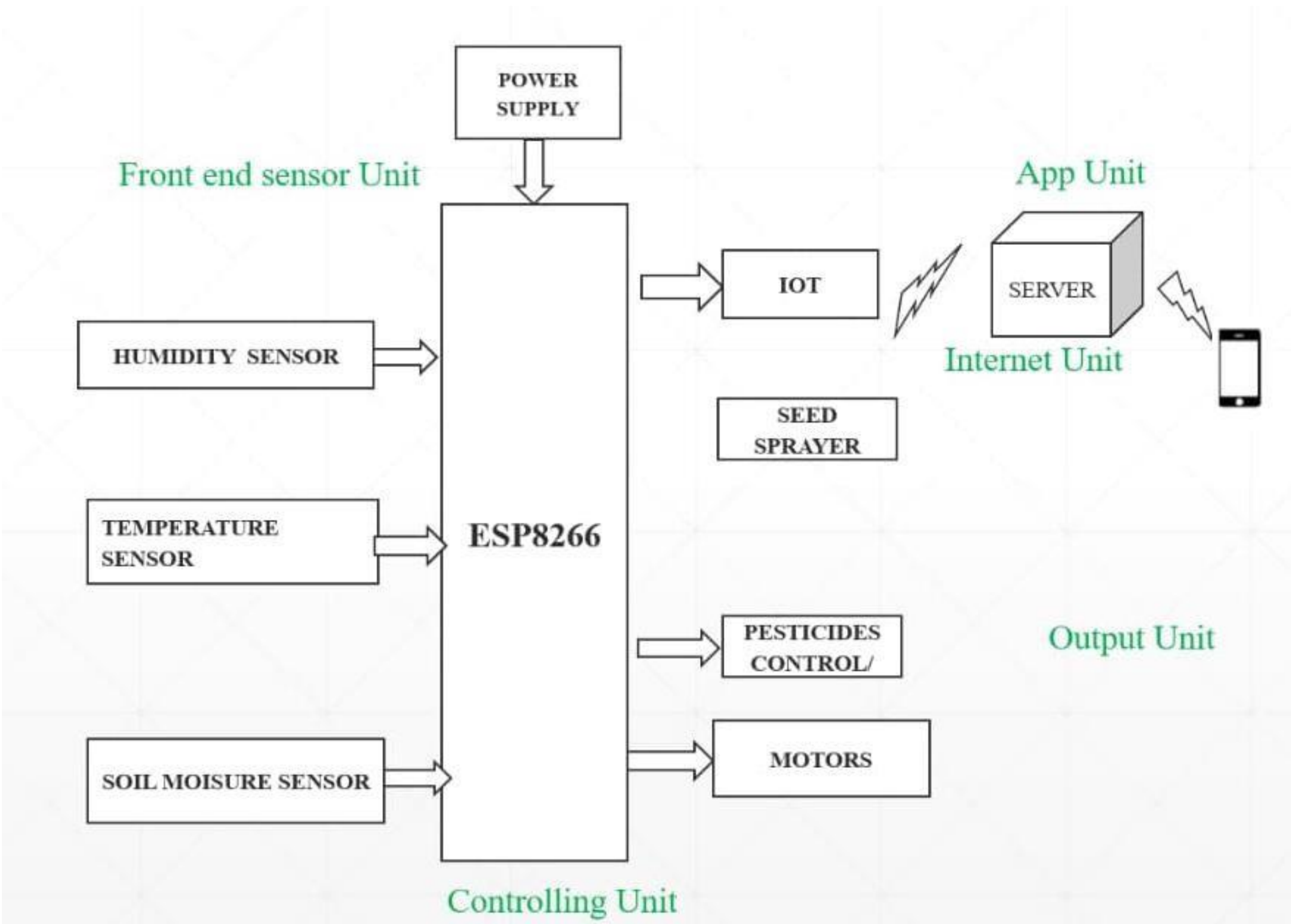

Fig. 5.1 System Architecture

CHAPTER 6

MODULES DESCRIPTION

6.1 MODULES

- Sensors Module
- Data Acquistion and Control Module
- Communication Module
- Cloud/Server Module
- User Interface Module

6.2 SENSORS MODULE

This module is responsible for continuously monitoring key environmental conditions—humidity, temperature, and soil moisture—which are critical for ensuring effective and safe pesticide spraying. Accurate sensing of these parameters allows the robotic system to make intelligent decisions on when and how much pesticide should be applied. By integrating these sensors, the robot not only minimizes chemical waste and environmental harm but also helps maximize crop health and yield. The system is designed to work in real-time, actively collecting and analyzing sensor data throughout the spraying operation.

The humidity sensor is used to measure the relative moisture content in the air. Since humidity levels directly impact the evaporation rate and absorption of sprayed pesticides, this sensor ensures spraying occurs only when environmental conditions are suitable. High humidity may reduce the effectiveness of chemicals due to quick condensation, while low humidity might cause rapid evaporation, resulting in incomplete coverage of the plant surface. By maintaining optimal humidity levels, the robot ensures uniform pesticide distribution and prevents wastage.

The temperature sensor plays a crucial role in determining the ambient thermal conditions of the agricultural field. Temperature variations significantly influence pest behavior and pesticide efficacy. Some chemicals become volatile at higher temperatures, posing health risks and reducing effectiveness, while cooler conditions may slow down the plant's uptake of pesticides. The temperature sensor captures accurate readings, which are then analyzed to decide whether it's safe and efficient to spray. This helps in avoiding harmful spraying during unsuitable temperature conditions.

The soil moisture sensor monitors the water content in the soil to ensure that the ground is not too wet or too dry before initiating pesticide spraying. Overly moist soil can lead to pesticide runoff, contaminating nearby water bodies and reducing chemical efficiency, while extremely dry conditions may indicate plant stress, requiring water rather than pesticide. This sensor helps determine the best spraying window and enhances overall crop treatment planning. It also supports irrigation decisions, making the robot a dual-purpose system in precision agriculture.

All three sensors work together to provide a comprehensive overview of the environmental status. These sensors are connected to the ESP8266/ESP32 microcontroller, which reads, processes, and transmits data wirelessly to the mobile application interface. This allows real-time updates and remote decision-making. The microcontroller continuously collects sensor data and checks whether each parameter falls within predefined thresholds. If all readings meet the optimal criteria, the robot proceeds with the pesticide spraying task. Otherwise, it alerts the operator or delays the operation until conditions improve.

Each sensor’s data is logged for further analysis and can be used to track trends over time, such as how environmental conditions affect crop growth or chemical performance. The GUI features options to monitor live sensor values, calibrate sensor thresholds, and trigger or pause spraying. Visual indicators and alerts help users take timely action when sensor values go beyond acceptable limits.

This module enhances precision agriculture by enabling smart, environment-aware spraying, reducing human error and increasing the sustainability of pesticide use. It empowers farmers to achieve higher yields while minimizing labor, input cost, and environmental impact. The modular design allows the system to be easily upgraded with additional sensors like pH or light sensors in the future.

Components

- **Humidity Sensor:** Continuously measures air moisture to determine chemical spray suitability.
- **Temperature Sensor:** Reads environmental temperature to adjust chemical timing and application.
- **Soil Moisture Sensor:** Detects ground wetness levels to prevent chemical runoff or spraying during stress periods.
- **ESP8266/ESP32 Microcontroller:** Processes sensor readings and communicates data to the mobile app.
- **Power Supply:** Provides a stable 5V DC source for all connected sensors and the microcontroller.
- **Wires & Connectors:** Used for linking the sensor module with the central control system.

Technical Considerations

- **Sensor Calibration:** Regular tuning is necessary to maintain measurement accuracy.
- **Threshold Logic:** Defined limits for each parameter guide the robot’s decision-making process.
- **Data Handling**: Real-time sensor data is processed locally and optionally logged for review.

- **Mobile App Integration:** Allows users to receive alerts, monitor live values, and initiate manual spraying when needed.
- **Power Efficiency:** Ensures longer operation time in the field with minimal energy consumption.

Functionality

This system supports autonomous and semi-autonomous operation based on environmental conditions. It increases the reliability of spraying actions and prevents misuse of chemicals by validating atmospheric and soil data in real time. By leveraging IoT and sensor integration, the robot adapts to different field conditions and crop types, improving operational flexibility and productivity. The sensor module is essential for sustainable agriculture, offering a smarter way to manage resources while safeguarding human health and the environment.

6.3 DATA ACQUISITION AND CONTROL MODULE

This module serves as the brain of the agricultural pesticide spraying robot, responsible for collecting sensor data, making logical decisions, and controlling actuators based on predefined environmental thresholds. It acts as the bridge between real-world inputs (sensor readings) and the robotic system's actions (spraying and movement). This intelligent system ensures that spraying operations are performed only when required and under optimal conditions, thereby promoting smart and sustainable agriculture.

The module begins with real-time data acquisition from all onboard sensors—humidity, temperature, and soil moisture. These sensors are interfaced with a microcontroller unit, primarily the ESP8266 or ESP32, which offers built-in Wi-Fi/Bluetooth capabilities and sufficient computational power for edge processing. Data from each sensor is read at regular intervals and temporarily stored in the microcontroller's memory. The readings are then passed through filtering and validation functions to ensure accuracy and consistency, eliminating noise or outliers caused by environmental fluctuations.

Once the data is validated, the control logic kicks in. The microcontroller compares the sensor readings against preset thresholds that have been defined based on crop type, environmental tolerance, and pesticide requirements. If all environmental values (e.g., temperature within 20–35°C, soil moisture between 30–60%, humidity above 40%) fall within the optimal range, the control module activates the spraying mechanism and drives the robot forward or to the target location. If any of the readings fall outside the set thresholds, the spraying process is halted automatically, and an alert is sent to the user via the mobile application interface. The motion control component is also managed by this module. Based on commands from the app or an automated path-finding algorithm, the microcontroller controls geared motors that drive the robot's wheels.

These motors receive PWM (Pulse Width Modulation) signals to control speed and direction. Obstacle avoidance can be optionally integrated using ultrasonic or IR sensors, all coordinated by the same data control unit. In addition to movement, this module manages the actuation of the spray nozzles, ensuring uniform pesticide application.

All captured sensor data and control decisions are logged and, optionally, transmitted to the mobile application using Wi-Fi or Bluetooth. This provides users with a transparent view of ongoing operations, sensor values, and decision-making criteria. The mobile app can override automatic operations if necessary, giving manual control over spraying and movement for special conditions or emergencies.

The Graphical User Interface (GUI) built into the app displays real-time sensor readings, system status, battery level, and operational logs. Users can initiate spraying, pause the robot, or adjust environmental thresholds remotely. This interactive control and monitoring system ensures that the robot operates in alignment with the user's needs and field requirements.

The system architecture supports scalability, allowing additional modules like GPS for navigation, camera vision for crop monitoring, or data analytics dashboards to be integrated in the future. With its flexible and modular structure, the data acquisition and control module forms the core intelligence of the smart spraying system.

Components

- **ESP8266 / ESP32 Microcontroller:** Central processing unit for data collection, decision-making, and communication.
- **Sensor Interfaces:** Connects the humidity, temperature, and moisture sensors to the microcontroller.
- **Motor Driver (e.g., L298N):** Controls wheel movement based on logic commands.
- **Relay / Pump Control Circuit:** Manages the on/off state of the spraying system.

- **Power Supply:** Typically, 5V/12V DC to support sensors, actuators, and the controller.
- **Communication Module:** Wi-Fi/Bluetooth for mobile app connectivity and data exchange.

Technical Considerations

- **Sensor Polling Frequency**: Optimized to collect data frequently without overloading the system.
- **PWM Control:** Used for speed regulation and directional control of motors.
- **Data Filtering:** Ensures clean and accurate readings using moving averages or basic Kalman filters.
- **Fail-Safe Logic:** Prevents spraying during abnormal environmental conditions or system errors.
- **Real-Time Logging**: Allows storing of environmental and operational data for future analysis.

Functionality

This module provides autonomous decision-making and intelligent control of the entire spraying robot. It balances automation with user control, ensuring both safety and efficiency. By integrating environmental data with responsive actuation, it minimizes pesticide misuse, reduces manual labor, and enhances agricultural productivity.

This makes it an essential component of modern precision farming, combining hardware control and data-driven logic into one seamless system.This module serves as the brain of the agricultural pesticide spraying robot, responsible for collecting sensor data, making logical decisions, and controlling actuators based on predefined environmental thresholds.

6.4 COMMUNICATION MODULE

The Communication Module is a vital component that facilitates the seamless exchange of data between the robot and the user. It enables real-time monitoring, remote control, and data synchronization through wireless technologies such as Wi-Fi or Bluetooth. This module ensures that the farmer or operator can interact with the robot without needing to be physically present, significantly improving safety, convenience, and efficiency in agricultural operations. The module is tightly integrated with both the sensor module and the control module, making it the core of interactive, IoT-based smart farming.

At the heart of this module lies the ESP8266 or ESP32 microcontroller, which offers built-in wireless communication capabilities. The Wi-Fi mode is generally preferred for long-range, high-speed data transfer, while Bluetooth may be used for short-range, energy-efficient communication. Through these channels, the microcontroller communicates sensor readings, operational status, and control signals to and from a dedicated mobile application interface, allowing the user to oversee the robot's activities from anywhere within network range.

The module continuously transmits live sensor data—including humidity, temperature, and soil moisture—to the user interface. This allows the farmer to make real-time decisions based on actual environmental conditions. The communication protocol is designed to be lightweight and reliable, ensuring quick data transmission and response even in areas with limited network bandwidth. In addition to transmitting data, the module also receives commands from the user such as "start spraying," "stop spraying," "move forward/backward," or "change threshold values."To support this functionality, the mobile application is equipped with a GUI dashboard that connects to the robot through the Communication Module.

This interface allows users to start or stop operations, adjust environmental parameters, view sensor logs, and monitor the robot's live status. Push notifications and alerts are also supported—if any parameter goes out of the safe range.

In scenarios where field internet connectivity is poor, the Communication Module can switch to offline or local hotspot mode, where the ESP32 creates its own Wi-Fi network that the mobile device can connect to directly. This ensures that the robot remains operational and controllable in remote agricultural zones with no cellular service.

The system architecture also allows for optional cloud integration, enabling long-term storage of environmental and operational data. This opens doors for analytics, historical trend tracking, and decision-making support based on past performance. Whether connected to a cloud server or operating in local mode, the Communication Module provides essential infrastructure for managing smart farming operations remotely.

Security is also a priority in the design of this module. Data encryption, access control, and authentication protocols are used to ensure only authorized users can send commands or access field data. The module also features fail-safe mechanisms—such as timeout-based disconnection alerts or fallback to manual mode in case of communication failure—ensuring reliability even under adverse conditions.

Components

- **ESP8266 / ESP32 Microcontroller:** Provides integrated Wi-Fi and Bluetooth for seamless wireless communication.
- **Antenna (Optional):** Enhances wireless signal range and quality for large field coverage.
- **Power Supply:** Stable 5V DC power source to support continuous data transmission.
- **Mobile Application Interface:** User-friendly GUI to send and receive commands and data.
- **Cloud/Local Server (Optional):** Used for remote data logging, analytics, and historical review.

Technical Considerations

- **Communication Protocols:** Utilizes HTTP, MQTT, or WebSocket depending on network type and data priority.
- **Latency Handling:** Optimized for minimal response delay to ensure timely robot control.
- **Range Optimization**: Use of long-range Wi-Fi or BLE protocols in open agricultural areas.
- **Data Security:** Includes authentication mechanisms to restrict unauthorized access.
- **Fallback Modes:** Supports switching between online and offline modes for uninterrupted operation.

Functionality

This Communication Module provides an intelligent bridge between the farmer and the robotic system. It offers real-time data streaming, command transmission, and system feedback, enabling precise control and dynamic response. Its integration with cloud-based platforms or direct app connectivity makes it highly flexible and scalable.As part of a smart pesticide spraying robot, it empowers users to make data-driven decisions, reduces manual involvement, and boosts productivity while ensuring operational safety and environmental compliance.

6.5 CLOUD/SERVER MODULE

The Cloud/Server Module acts as the central intelligence unit of the smart agricultural system, responsible for processing, storing, analyzing, and delivering sensor and rover data to users through intuitive web or mobile platforms. It ensures seamless communication between the autonomous rover, various sensor modules, and the end user by leveraging modern cloud computing technologies and advanced data analytics pipelines.At the core of this module lies a cloud platform, such as AWS IoT, ThinkSpeak, Google Cloud IoT, Firebase, or Azure IoT Hub.

These services offer scalable infrastructure to capture, store, and transmit sensor data in real time, ensuring that users have immediate access to environmental metrics like soil moisture, humidity, and weather conditions. The cloud also provides robust security, authentication, and remote device management, making it a critical component in autonomous operations.To maintain historical records and support long-term analysis, the system employs SQL or NoSQL databases such as MySQL, Firebase Realtime Database, or AWS DynamoDB. These databases store data from various modules—ranging from field sensors to rover telemetry—enabling structured and efficient data retrieval for analytics and decision-making.

The data analytics pipeline within this module is responsible for interpreting raw sensor inputs into actionable insights. By applying algorithms and statistical models, it can track trends in soil moisture levels, predict irrigation needs, detect anomalies in plant health, and assess crop growth patterns. These insights not only support autonomous decision-making by the system but also enhance user awareness for timely interventions.A web interface acts as the user-facing layer of the module.Built using modern front-end frameworks such as React.js or Angular, the dashboard provides real-time visualizations, alerts, and control options.

Users can view live data from the field, review historical graphs, and control rover functions such as movement paths and spraying schedules. The interface is designed with user experience in mind, allowing for responsive operation across devices like smartphones, tablets, or desktop. By bridging the gap between field data and user interaction, the Cloud/Server Module plays a pivotal role in making precision agriculture truly intelligent, autonomous, and remotely manageable. Its integration ensures reliable communication, long-term data storage, intelligent processing, and user-friendly visualization—all critical elements in a modern agricultural automation ecosystem.

Functionality

The primary function of the Cloud/Server Module is to collect data from the autonomous rover and environmental sensors, process and analyze it, and then make it accessible through a user-friendly interface. It enables real-time and historical data visualization, remote monitoring, and intelligent control logic for precision agricultural activities. Additionally, it provides the backbone for automation by integrating analytics-driven decision-making, such as adjusting irrigation schedules based on soil moisture or weather conditions. This module serves as the digital brain of the system, ensuring seamless communication, coordination, and data-driven operations between field devices and end users.

Components

- **Cloud Platform:** Handles real-time data ingestion and remote communication. Examples include AWS IoT, Google Cloud IoT, Firebase, ThinkSpeak, or Azure IoT Hub.
- **Database System:** Stores sensor and rover data in either SQL (MySQL) or NoSQL (Firebase Realtime Database, AWS DynamoDB) format for easy retrieval and analysis.
- **Data Analytics Engine:** Performs advanced analytics to derive meaningful patterns from raw data, such as crop health insights, environmental trends, and predictive irrigation needs.
- **Web Interface:** A responsive dashboard built using frameworks like React.js or Angular, used for monitoring, control, and visualization of data.
- **APIs & Middleware:** Manage data flow between hardware (sensors/rover) and the cloud, ensuring secure and efficient communication.
- **Authentication & Access Control**: Ensures only authorized users can access, control, or modify data and settings.

Technical Considerations

- **Real-Time Data Sync:** Ensures low-latency communication between the rover and cloud for live monitoring and immediate alerts.
- **Scalability:** The infrastructure must be scalable to accommodate increased data flow from additional sensors or multiple rovers deployed over larger fields.
- **Security & Privacy:** Implements encryption, secure data transmission protocols, and user authentication to safeguard sensitive agricultural data.
- **Reliability:** Utilizes fault-tolerant cloud services and redundancy mechanisms to ensure system uptime and data availability, even under unstable network conditions.
- **Storage Optimization:** Efficiently handles large volumes of time-series data by using optimized database schemas and automatic pruning or archiving strategies.
- **Data Accuracy & Validation:** Incorporates error-checking mechanisms to ensure the accuracy of sensor readings and prevent misinterpretation of noisy or corrupted data.

6.6 USER INTERFACE MODULE

The User Interface (UI) Module acts as the primary point of interaction between the user and the agricultural robot. Designed to be intuitive and responsive, this module allows farmers to control, monitor, and manage the robot's actions in real time through a graphical interface. The UI enables users to access key information such as sensor readings, robot status, spraying activity, and movement tracking, making the system more accessible and efficient, especially for those without technical backgrounds.

This module is typically deployed as a mobile application built using Android Studio or compatible cross-platform frameworks. The mobile app connects to the robot via Wi-Fi or Bluetooth (enabled by the Communication Module) and provides a real-time dashboard to oversee the robot's operation. The UI layout is structured with simplicity and ease of use in mind, offering dedicated panels for live sensor data, system controls, historical logs, and alerts.

The main dashboard displays real-time environmental parameters captured by sensors—humidity, soil moisture, and temperature. It also shows the current operational state of the robot, including whether it is actively spraying, moving, or idle. The user can start or stop the spraying process, navigate the robot manually through directional buttons, and even switch between automatic and manual operation modes. Additionally, users can modify threshold values (e.g., moisture level to trigger spraying), allowing dynamic control based on varying field conditions.

An essential feature of this module is live monitoring. The app continuously updates the GUI with real-time data received from the robot, ensuring that the user is always informed of the current situation in the field. This includes updates on battery level, system status, communication signal strength, and motor activity. All data is presented using interactive graphs, meters, and color-coded indicators to enhance visual understanding and responsiveness.

The UI also incorporates alert and notification systems. When a sensor value crosses a danger threshold (e.g., high temperature or low moisture), the app pushes an alert to the user and may even sound an alarm.

This warning system is vital for ensuring prompt corrective action and preventing damage to crops or robot hardware. Notifications are also used to inform users when a task is completed or if there is a communication failure.The app supports a settings panel where users can customize the system's operational parameters, such as spraying intervals, motor speed, sensor polling rates, and notification preferences. It also includes data logging features, allowing users to view historical sensor values and robot activities over time. These logs help track field conditions and evaluate system performance across different seasons.

In addition to direct control, the User Interface Module also includes manual override options, which allow the user to take full control of the robot if the automatic mode encounters obstacles or unpredictable situations. This hybrid control capability improves flexibility and ensures uninterrupted operations in dynamic agricultural environments.

The UI design follows best practices in mobile UX, with large touch-friendly buttons, minimal latency interactions, and responsive layouts suitable for both phones and tablets. The module ensures accessibility through multilingual support and adjustable font sizes, making it inclusive for diverse user bases.

Components

- **Mobile Application (Android/iOS):** The primary platform for displaying and controlling robot operations.
- **UI Dashboard:** Includes panels for sensor data, robot status, and real-time control.
- **Notification System:** Push alerts for threshold violations, status updates, and task completions.
- **Settings and Logs:** Customization panel for parameters and a log section for historical data.
- **Connectivity Interface:** Handles pairing with ESP8266/ESP32 over Wi-Fi or Bluetooth.

Technical Considerations

- **Real-Time Data Syncing:** Efficient UI updates to reflect current robot status with minimal delay.
- **Low Latency Controls:** Immediate response to user commands for movement or spraying.
- **Responsive Design:** Adapts to various screen sizes and resolutions.
- **Secure Access:** Ensures that only authorized users can control or change robot settings.
- **Customizable Thresholds:** Allow users to adjust environmental parameters based on crop type and climate.

Functionality

The User Interface Module plays a critical role in enhancing usability and operational transparency. It bridges the gap between the farmer and the robot by providing a smooth, informative, and customizable control environment. With its real-time monitoring, intuitive controls, alert system, and data visualization features, the UI module turns complex automation into a user-friendly experience. This module ensures that the robot operates efficiently while empowering the user with full control and field awareness.

CHAPTER 7

CONCLUSION AND FUTURE ENHANCEMENT

7.1 CONCLUSION

In conclusion, the integration of intelligent irrigation scheduling and autonomous spraying systems marks a significant step forward in precision agriculture. These systems enhance efficiency and sustainability by optimizing resource use, though challenges such as design limitations, flow constraints, and coordination between sectors still need addressing.Their effectiveness depends on accurate field evaluations and reliable rainfall forecasts.Autonomous spraying systems deliver safe and precise chemical applications, even in complex environments.Moreover, the modular, adaptable nature of autonomous sprayers offers safe, precise operations even in complex terrains, paving the way for broader applications in modern farming.

7.2 FUTURE ENHANCEMENT

Enhancing scalability and adaptability with advanced machine vision and AI will improve precise navigation in dynamic environments. Expanding its capabilities to include harvesting, pruning, weeding, and soft tilling can boost year-round utility and cost-effectiveness.Integrating real-time cloud-based data logging and remote control will streamline farm management and performance monitoring. Improvements in battery life, charging efficiency, and terrain adaptability will ensure reliable long-duration operations. Finally, extensive field testing in varied conditions will validate robustness for future large-scale commercial deployment.

Here are some future directions for enhancing the system

- Advanced Sensor Integration and AI
- Expanded Functionalities
- Enhanced IoT Connectivity and Data Analytics
- Improved Mechanical and Power Systems
- Robust Field Testing and Scalability.

Moreover, addressing standards, ethical guidelines, and developing cost- effective hardware solutions will contribute to responsible and widespread deployment The project's future lies in creating a versatile ,user friendly automatic seeding and watering in the agri-bot using IoT system that significantly contributes to public safety and prevent from accidents.

APPENDIX A

SOURCE CODE

```
#include <ESP8266WiFi.h>
#include "DHT.h"
// WiFi Credentials
const char* ssid = "SMART"; // SSID of your Wi-Fi
const char* password = "123456789"; // Password of your Wi-Fi
WiFiServer server(80);
// Pin definitions
int gas_pin = A0;
int gas_val = 0;
int m1 = D0, m2 = D1, m3 = D2, m4 = D3;
int relay1 = D4, relay2 = D8;
const int trigPin = D6;
const int echoPin = D5;
// Sensor variables
#define SOUND_VELOCITY 0.034
#define CM_TO_INCH 0.393701
long duration;
float distanceCm;
float distanceInch;
// DHT Sensor setup
#define DHTPIN D7
#define DHTTYPE DHT11
```

```
DHT dht(DHTPIN, DHTTYPE);
float h = 0, t = 0, f = 0;
// State variables
int val = 0, val1 = 1, val2 = 1;
String msg = "STOP", msg1 = "RELAY1 OFF", msg2 = "RELAY2 OFF";
void setup() {
 dht.begin();
 pinMode(trigPin, OUTPUT);
 pinMode(echoPin, INPUT);
 pinMode(m1, OUTPUT);
 pinMode(m2, OUTPUT);
 pinMode(m3, OUTPUT);
 pinMode(m4, OUTPUT);
 pinMode(relay1, OUTPUT);
 pinMode(relay2, OUTPUT);
 Serial.begin(9600);
 Serial.println();
 Serial.print("Connecting to ");
 Serial.println(ssid);
 WiFi.begin(ssid, password); // Connect to Wi-Fi
 while (WiFi.status() != WL_CONNECTED)
{
// Wait until connected
   delay(500);
```

```
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");
  server.begin();
  Serial.println("Server started");
  Serial.println(WiFi.localIP()); // Print the IP address
  delay(3000);
}
void loop() {
  // Robot Movement Control
  if (val == 1) {
    Serial.println("Moving forward");
    digitalWrite(m1, HIGH);
    digitalWrite(m2, LOW);
    digitalWrite(m3, HIGH);
    digitalWrite(m4, LOW);
  } else if (val == 0) {
    Serial.println("Stopped");
    digitalWrite(m1, LOW);
    digitalWrite(m2, LOW);
    digitalWrite(m3, LOW);
digitalWrite(m4, LOW);
  }
```

```
  // Read DHT sensor
  h = dht.readHumidity();
  t = dht.readTemperature();
  f = dht.readTemperature(true);
  // Read Gas Sensor
  gas_val = analogRead(gas_pin);
  // Print sensor data to serial monitor
  Serial.print("Humidity: "); Serial.println(h);
  Serial.print("Temperature (C): "); Serial.println(t);
  Serial.print("Temperature (F): "); Serial.println(f);
  Serial.print("Gas Value: "); Serial.println(gas_val);
  // Read Ultrasonic Distance Sensor
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distanceCm = duration * SOUND_VELOCITY / 2;
  distanceInch = distanceCm * CM_TO_INCH;

 // Print distance
  Serial.print("Distance (cm): "); Serial.println(distanceCm);
  Serial.print("Distance (inches): "); Serial.println(distanceInch);
```

```
// Handle client request
WiFiClient client = server.available();
if (!client) {
  return;
}
String req = client.readStringUntil('\r');
Serial.println(F("Request: "));
Serial.println(req);
// Handle GPIO requests
if (req.indexOf(F("/gpio/0")) != -1) {
  val = 0;
  msg = "STOP";
} else if (req.indexOf(F("/gpio/1")) != -1) {
  val = 1;
  msg = "FORWARD";
} else if (req.indexOf(F("/gpio/3")) != -1) {
  Serial.println("Relay 1 ON");
  digitalWrite(relay1, HIGH);
  val1 = 0;
  msg1 = "RELAY1 ON";
} else if (req.indexOf(F("/gpio/4")) != -1) {
  Serial.println("Relay 1 OFF");
  digitalWrite(relay1, LOW);
  val1 = 1;
```

```
    msg1 = "RELAY1 OFF";
  } else if (req.indexOf(F("/gpio/5")) != -1) {
    Serial.println("Relay 2 ON");
    digitalWrite(relay2, HIGH);
    val2 = 0;
    msg2 = "RELAY2 ON";
  } else if (req.indexOf(F("/gpio/6")) != -1) {
    Serial.println("Relay 2 OFF");
    digitalWrite(relay2, LOW);
    val2 = 1;
    msg2 = "RELAY2 OFF";
  } else {
    Serial.println(F("Invalid request"));
  }
  // Prepare response
  String s = "HTTP/1.1 200 OK\r\nContent-Type: text/html\r\n\r\n<!DOCTYPE html><html><head><title>Environment Monitoring</title><style>";
  s += "a:link {background-color: YELLOW; text-decoration: none;} table, th, td {text-align: center; padding: 8px;} </style>";
  s += "<meta http-equiv='refresh' content='3'></head><body bgcolor='lightgreen'>";
  s += "<h1 ALIGN=CENTER>ENVIRONMENT MONITORING</h1><h2 ALIGN=CENTER>Sensor Details</h2><table border=1 ALIGN=CENTER>";
  // Display sensor data in a table
  s += "<tr><th>Humidity (%)</th><td><h2>" + String(h) + "</h2></td></tr>";
```

```
  s += "<tr><th>Temperature (C)</th><td><h2>" + String(t) + "</h2></td></tr>";
  s += "<tr><th>Speed</th><td><h2>" + String(gas_val) + "</h2></td></tr>";
  s += "<tr><th>Level (cm)</th><td><h2>" + String(distanceCm) + "</h2></td></tr>";
  s += "</table><br>";
  // Buttons for controlling robot and relays
  s += "<a href='http://" + WiFi.localIP().toString() + "/gpio/" + String(1 - val) + "'><h1>ROBO
- " + msg + "</h1></a>";
  s += "<a href='http://" + WiFi.localIP().toString() + "/gpio/" + String(3 + (1 - val1)) +
"'><h1>" + msg1 + "</h1></a>";
  s += "<a href='http://" + WiFi.localIP().toString() + "/gpio/" + String(5 + (1 - val2)) +
"'><h1>" + msg2 + "</h1></a>";
  s += "</body></html>";
  // Send the response to the client
  client.print(s);
  delay(100);
}
```

APPENDIX B

SCREENSHOTS

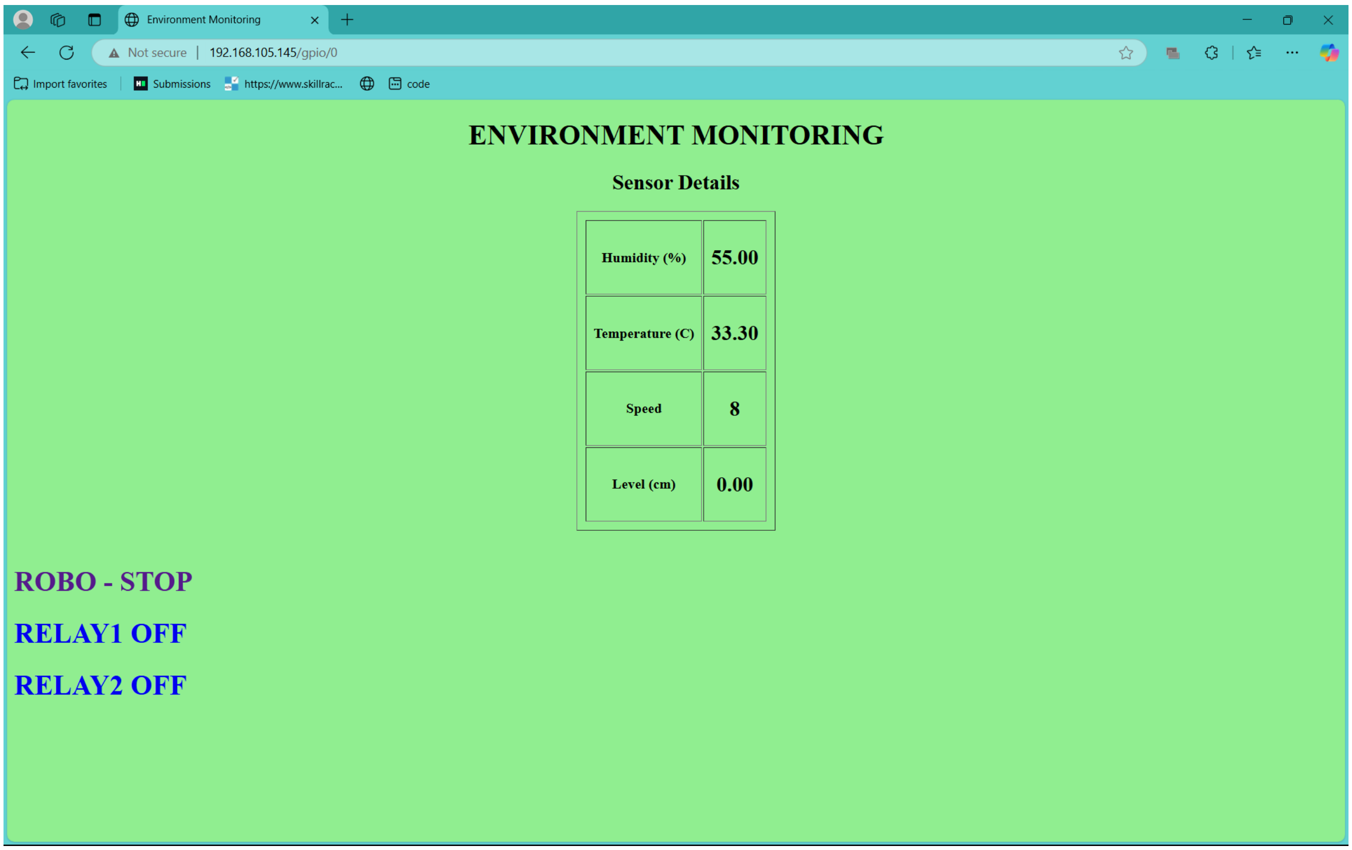

Fig.B.1 Interface

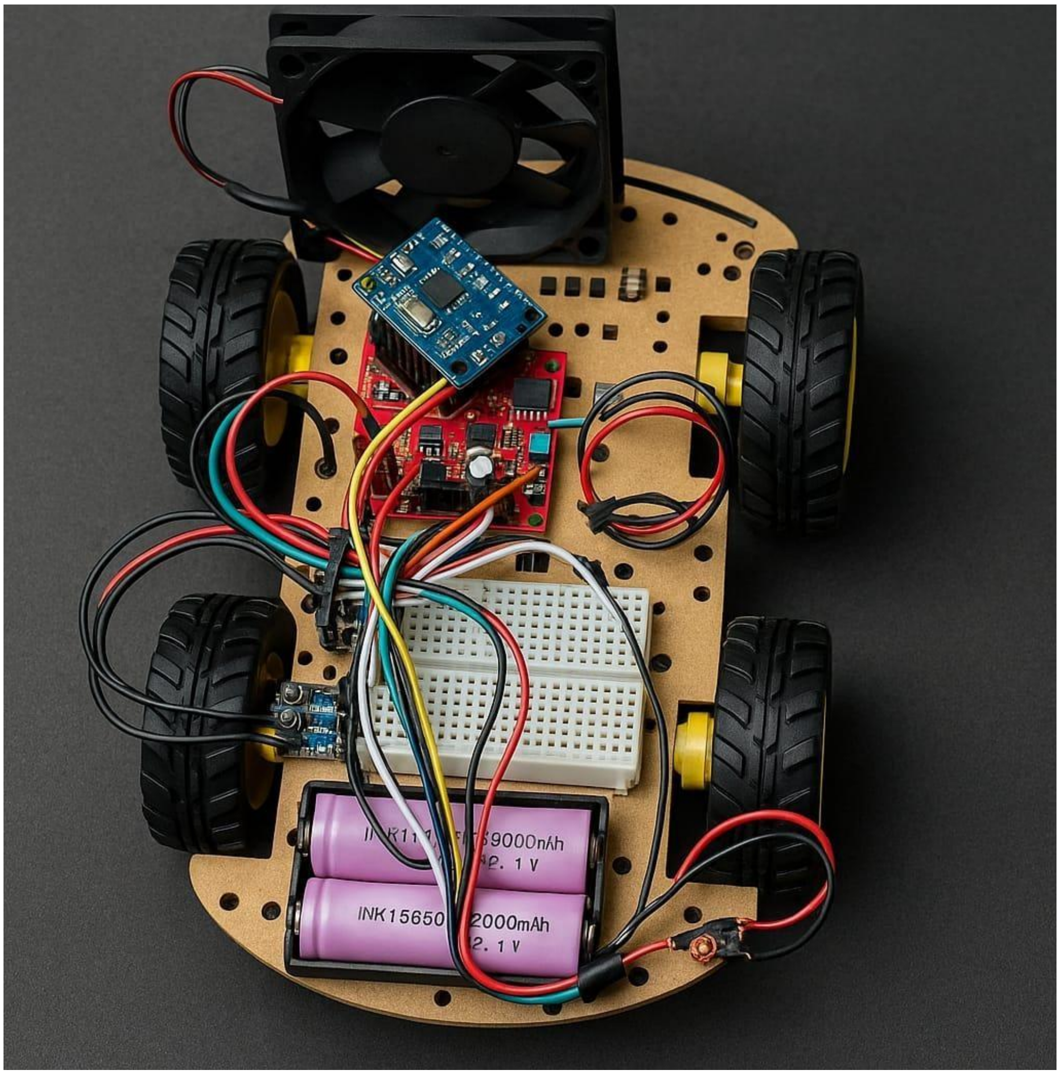

Fig.B.2 Demonstration

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