



Rocker - Bogie Mechanism For Smart Farming

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ABSTRACT

This project presents a smart agricultural robot based on the rocker-bogie mechanism, designed to assist farmers with soil monitoring, seed dispensing, water spraying, and live visual field observation. Using an ESP32 controller with IoT connectivity, the system measures soil moisture and temperature, sends real-time data to the Arduino IoT Cloud, and allows remote control of movement, seed dispensing, and spraying operations. The integration of the ESP32-CAM module provides live video streaming, enabling users to visually monitor farming activities and field conditions from anywhere. The robot enhances precision agriculture by reducing manual labor, improving seed and spray accuracy, and supporting real-time decision-making through IoT-enabled monitoring and camera feedback.

CHAPTER 1

INTRODUCTION

Modern agriculture faces several limitations, including irregular terrains, shortage of skilled labor, and the need for efficient monitoring of soil conditions. Traditional farming methods involve repetitive manual tasks such as checking soil health, planting seeds, and spraying water or fertilizers. These operations are time-consuming and often lack precision, resulting in reduced productivity.

With the advancement of embedded systems and IoT technologies, smart robotic solutions are becoming practical for small-scale and large-scale farming. The rocker-bogie mechanism, widely used in Mars Rover systems, provides excellent stability and mobility on uneven agricultural fields. Integrating this with the ESP32 microcontroller enables robust automation, remote control, and continuous data monitoring.

This project proposes a multipurpose agricultural robot equipped with soil moisture and temperature sensors, a seed-dispensing servo, and a water-spraying mechanism. All operations are controlled from the Arduino IoT Cloud dashboard using separate widgets for forward movement, seed dispensing, spraying, reverse movement, and message display. The system supports real-time decision-making by displaying sensor readings on the cloud interface and enabling farmers to control field activities from anywhere.

CHAPTER 2 LITERATURE REVIEW

➤ **Llontop & Ramos, “Optimization of Rocker–Bogie Suspension System for Agricultural Robots” (2025)**

The study optimized rocker-bogie designs for stability over rough farm surfaces. It demonstrated superior traversal compared to traditional wheel systems.

Limitation: Focused only on mechanical mobility; no IoT or farming tasks.

➤ **Tsimpidi et al., “UGV-Based Robotic Platform for Soil Moisture Remote Sensing” (2025)**

This study introduced an unmanned ground vehicle (UGV) equipped with soil moisture sensors for precision remote sensing. The robot autonomously navigated farmland and wirelessly transmitted moisture readings to assist in optimizing irrigation scheduling. Limitation: The system was limited to soil sensing only and did not perform any active farming tasks such as seeding or spraying.

➤ **B. Rakesh et al., “Smart Spraying Robot for Precision Farming Using ESP32” (2024)**

This research introduced an agricultural spraying robot using an ESP32 controller with IoT dashboard support. It effectively reduced water wastage and improved spray uniformity.

Limitation: Did not include soil monitoring or seed dispensing.

➤ **V. Ramesh & A. Kumar, “Autonomous Seeding and Spraying Robot Using Microcontroller” (2024)**

This study developed a robot capable of performing two major farming operations: seeding using a servo-controlled dispensing mechanism and spraying using a motor-driven pump.

Limitation: The system did not use IoT cloud platforms and relied on RF-based manual control, limiting remote accessibility and data logging.

➤ **Shubham Sharma et al., “IoT-Based Smart Agriculture Robot for Seed Sowing and Soil Monitoring” (2023)**

This work developed an agricultural robot capable of seed dispensing and soil moisture monitoring using IoT. The system provided remote access to sensor readings but lacked advanced terrain mobility.

Limitation: Normal-wheel mobility; not suitable for uneven terrain.

➤ **Anmol Lukkad et al., “Rocker-Bogie Rover for Agricultural Applications” (2023)**

This research presented a rocker–bogie rover capable of navigating uneven agricultural terrain while performing pesticide spraying and sensor-based environmental monitoring. The rover demonstrated enhanced stability over soil irregularities, making it suitable for outdoor farm operations. A Bluetooth module was used for wireless control, enabling manual operation from a short distance.

Limitation: The system relied solely on Bluetooth control and lacked IoT cloud features for long-distance monitoring or automation.

➤ **S. Ravikumar and P. Kiran, “Design of Seed Sowing Robot Using Arduino and IoT” (2022)**

The study implemented a low-cost IoT-based seed-sowing system using servos and soil sensors. Remote control was possible through Wi-Fi communication.

Limitation: No spraying mechanism; limited to seed dispensing only.

➤ **Prasad et al., “IoT Integrated Smart Farm Machine for Multi-Operation Farming” (2022)**

This paper proposed a multifunctional IoT-enabled farm machine capable of soil monitoring, irrigation control, and spraying operations. Real-time sensor data was sent to an IoT dashboard to assist farmers in making timely decisions. The system successfully demonstrated the integration of sensing and actuation in a single IoT platform to improve farm efficiency.

Limitation: The design did not include servo-based automated seed dispensing, limiting its application in sowing operations.

CHAPTER 3

PROBLEM STATEMENT

Farmers lack an automated system capable of monitoring soil conditions and performing essential tasks like seed dispensing and water spraying while operating on uneven terrain. Manual processes are labor-intensive and imprecise, and farmers cannot remotely control or monitor field activities. Therefore, there is a need for a stable robotic platform capable of performing multiple farming operations with IoT-based real-time monitoring.

CHAPTER 4 OBJECTIVES

- To design a stable mobile robot using the rocker-bogie mechanism for smooth movement on uneven agricultural terrain.
- To measure soil moisture and temperature and automate seed dispensing and water spraying using ESP32-based control.
- To transmit live video from the ESP32-CAM module to the monitoring interface for real-time field observation.

CHAPTER 5

PROPOSED METHODOLOGY

5.1 BLOCK DIAGRAM :

The Smart IoT-Enabled Parcel Sorting System follows a structured methodology in which the ESP32 microcontroller coordinates parcel identification, validation, and sorting.

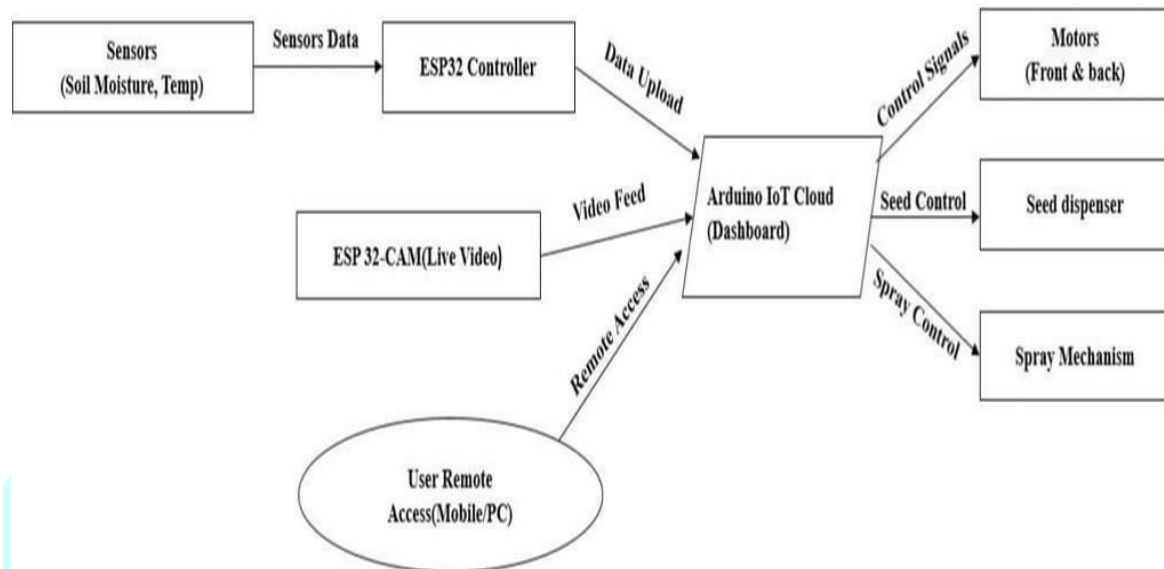


Figure 5.1: Block diagram.

The above Figure 1 shows the System Block Diagram. The proposed system uses the ESP32 microcontroller as the central processing unit, responsible for managing sensors, actuators, and communication with the Arduino IoT Cloud. Soil moisture and temperature sensors continuously collect environmental readings, which the ESP32 processes and uploads to the cloud in real time. Alongside this, the ESP32-CAM module initializes during startup and begins live video streaming, allowing farmers to visually monitor the field and robot activity remotely. The IoT dashboard displays updated sensor values and the live video feed, enabling users to make informed decisions about field operations based on both numerical and visual data.

The robot's operational mechanisms are controlled entirely through the Arduino IoT Cloud dashboard. When the forward or backward movement buttons are pressed, the ESP32 sends commands to the motor driver, enabling the robot to navigate across farmland.

For seed dispensing, the ESP32 activates a servo motor that opens and closes the seed container in a precise timed sequence whenever the user presses the corresponding dashboard button. Similarly, pressing the water spray button triggers the mini water pump or spraying motor, allowing controlled irrigation or pesticide application. During all these actions, the ESP32-CAM continuously streams live footage, enabling the operator to visually confirm each task in real time.

To ensure robust operation, the system incorporates automatic reconnection logic, so if the Wi-Fi link

drops, the ESP32 attempts to reconnect until successful. The robot runs in a continuous loop, updating sensor values, maintaining video streaming, and waiting for user inputs. A dedicated message widget on the dashboard provides status alerts such as “Seeds Dispensed,” “Spraying Activated,” “Movement Started,” or “Low Moisture Detected.” Through this integration of sensing, actuation, and live visual feedback, the methodology ensures a fully interactive, remotely accessible smart farming solution.

In addition to the primary sensing and actuation workflow, the system incorporates cloud-based synchronization features to ensure uninterrupted communication between the ESP32 and the Arduino IoT Cloud. The ESP32 continuously monitors the Wi-Fi connection status and automatically reconnects if the connection is lost. This guarantees stable uplink of soil data and reliable execution of user commands. Furthermore, debouncing techniques and software filtering are applied to sensor inputs to ensure that only accurate and stable readings are transmitted to the cloud, reducing noise and increasing system reliability.

5.2 FLOW CHART WITH WORKING MECHANISM

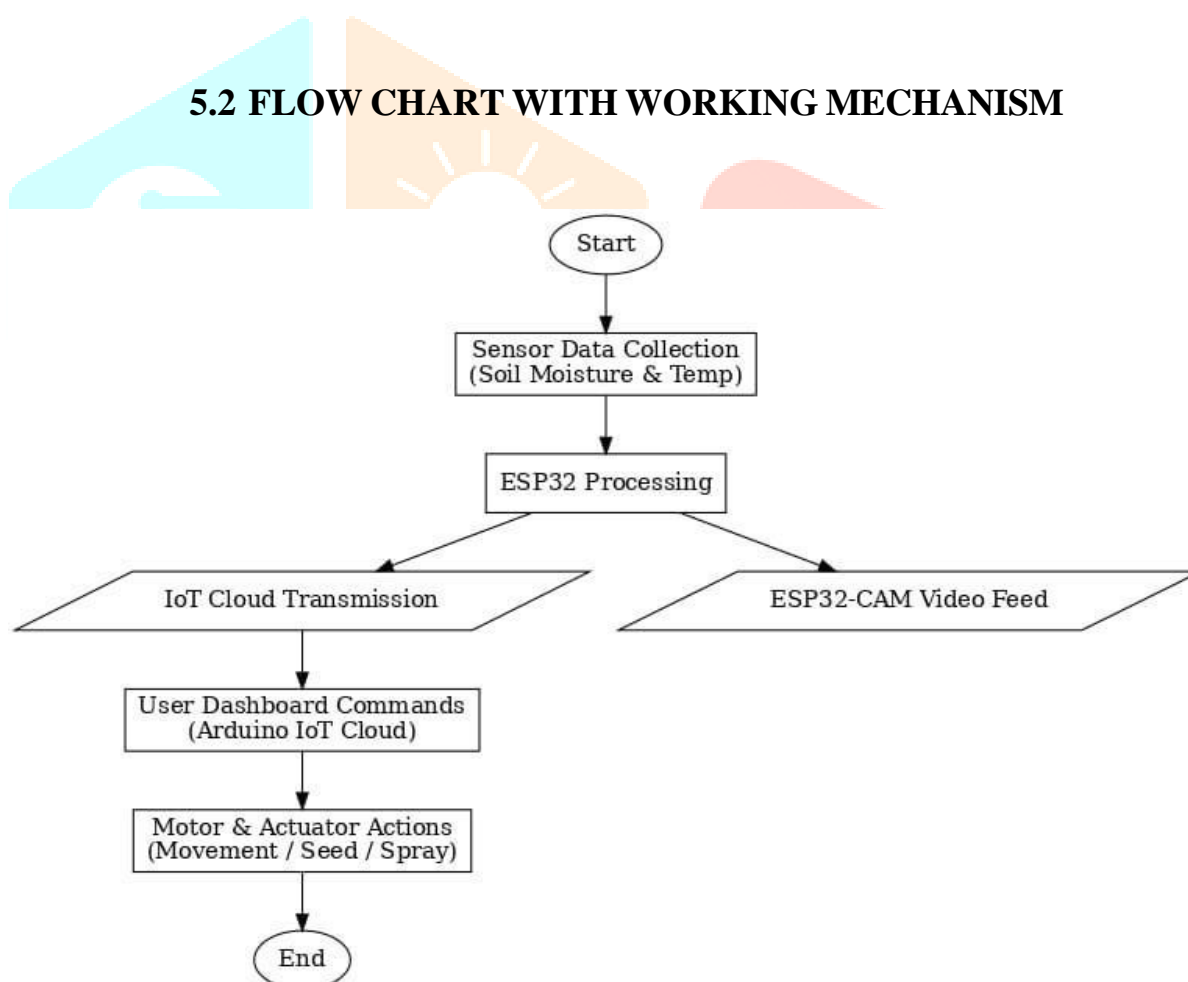


Figure 5.2: System flow chart

Flow Chart Explanation:

The working process begins with powering on the robot, after which the ESP32 initializes all sensors, the ESP32-CAM module, and establishes a connection to the Arduino IoT Cloud.

Once connected, the system continuously reads soil moisture and temperature values and uploads them to the IoT dashboard in real-time. Simultaneously, the ESP32-CAM starts streaming live video footage, allowing the user to monitor the field visually through the cloud interface. If any network interruption

occurs, the ESP32 automatically attempts to reconnect to ensure uninterrupted data flow and video transmission.

In the next stage of the flow, the user interacts with the Arduino IoT Cloud dashboard to control the robot's operations. Pressing the forward button sends a command to the motor driver, moving the robot forward, while the backward button reverses the motion. When the seed dispensing button is pressed, the ESP32 activates the servo motor to open and close the seed container in a controlled manner. Similarly, the water spray button triggers the sprayer motor, allowing precise irrigation. Throughout this process, the ESP32-CAM continues to provide a live stream, helping the user observe the robot's actions remotely.

The final stage of the flow involves displaying system messages and providing real-time feedback to the farmer. The message widget on the dashboard updates the user with important notifications such as "Seeds Dispensed," "Spraying Completed," "Movement Activated," or warnings like "Soil Moisture Low." The robot runs in a continuous loop, updating sensor data, maintaining video feed, and waiting for user input. This integrated approach ensures accurate sensing, safe actuation, and complete remote visibility through the ESP32-CAM, making farming tasks more efficient and user-friendly.

Circuit Diagram Explanation

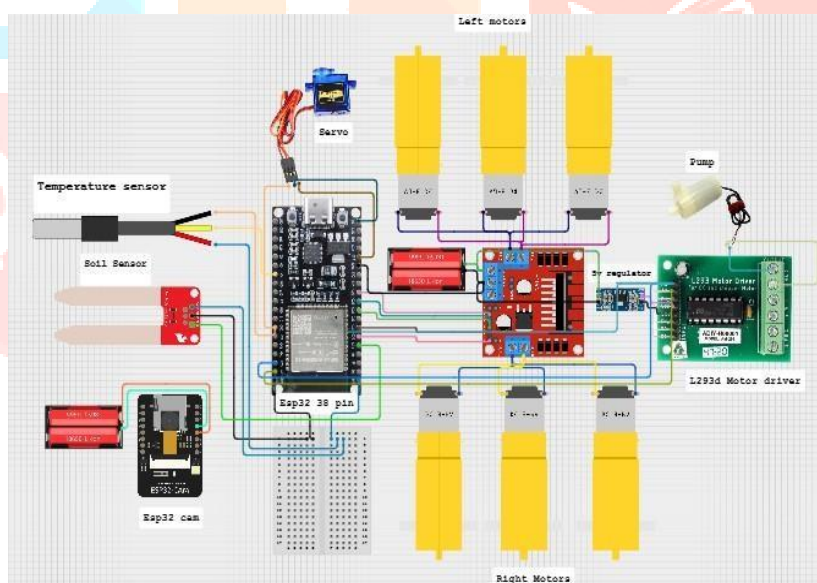


Figure 15: System Circuit Diagram

As shown in the above figure 15, The designed system is centred around the ESP32 (38-pin) microcontroller, which acts as the main control unit responsible for coordinating sensing, processing, communication, and actuation tasks. The circuit is powered using a regulated DC supply, where a voltage regulator ensures that appropriate voltage levels are maintained for different components.

While the ESP32 and sensors operate at low voltage levels such as 3.3V or 5V, the motor drivers and pump require higher current, and therefore proper regulation is essential to ensure stable and safe operation of the system.

The ESP32 continuously interfaces with the soil moisture sensor and temperature sensor to collect environmental data from the field. The soil moisture sensor is connected to an analog input pin of the

ESP32, allowing it to measure the water content in the soil, while the temperature sensor monitors the surrounding temperature conditions. These sensor values are processed by the ESP32 and transmitted to the Arduino IoT Cloud via a WiFi connection, enabling real-time remote monitoring.

For movement and actuation, the circuit incorporates two motor driver modules, namely the L298N and L293D motor drivers. These drivers are used to control multiple DC motors arranged on the left and right sides of the robot. The ESP32 sends control signals to these drivers, which in turn drive the motors in different directions, enabling forward, backward, and turning movements. This differential control mechanism allows the robot to navigate efficiently across the field.

In addition to movement, the system includes a seed dispensing mechanism controlled by a servo motor. The servo motor is connected to a PWM pin of the ESP32 and operates based on user commands received from the IoT dashboard. When activated, the servo rotates to open the seed container and release seeds, and then returns to its original position to close the container, ensuring controlled and precise dispensing. The water spraying system is implemented using a DC pump connected through the motor driver. When the spray command is triggered from the IoT interface, the ESP32 activates the pump, allowing water to be sprayed over the field for irrigation purposes. This enables efficient and targeted watering, reducing manual effort.

To enhance monitoring capabilities, an ESP32-CAM module is integrated into the system. This module provides live video streaming of the field, allowing the user to visually monitor the robot's operation in real time. The ESP32-CAM operates alongside the main ESP32 and transmits video data over the same WiFi network.

CHAPTER 6

COMPONENTS REQUIRED

6.1 Hardware components

➤ ESP32 Development Board

As shown in the below figure3, A powerful microcontroller with built-in Wi-Fi and Bluetooth used for processing sensor data, controlling motors, and sending real-time updates to Arduino IoT Cloud. It is the central controller for the entire sorting system.



Figure 6.1: ESP32 Development Board

➤ **ESP32 CAM Module**

As shown in the below figure4, The ESP32-CAM is a Wi-Fi enabled microcontroller module with an OV2640 camera used for live video streaming. It sends real-time visuals of the robot's surroundings to the Arduino IoT Cloud dashboard. This helps the user remotely monitor field conditions and verify seed dispensing and spraying actions.



Figure 6.2: ESP32 CAM Module

➤ **Soil Moisture Sensor**

As shown in the below figure5, Measures the moisture level in the soil based on resistance changes. When the soil is dry, resistance is high; when wet, resistance decreases.

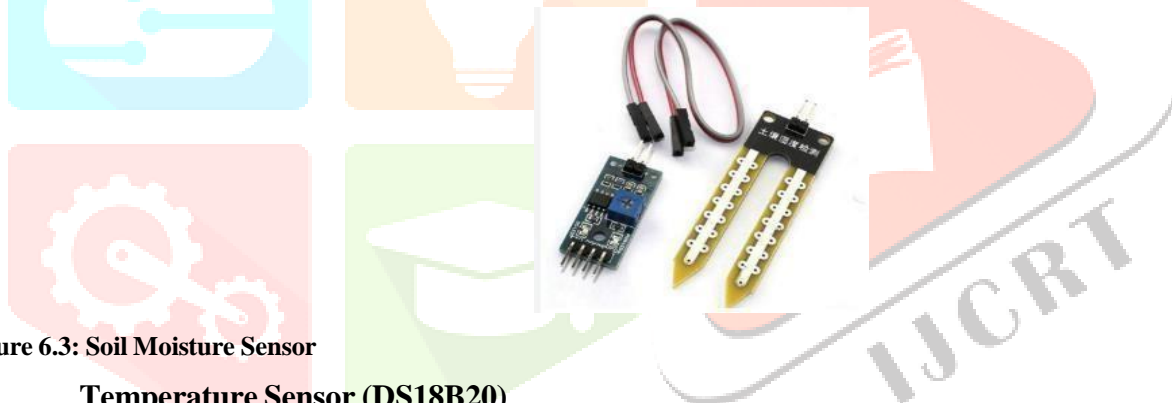


Figure 6.3: Soil Moisture Sensor

➤ **Temperature Sensor (DS18B20)**

As shown in the below figure6, Digital temperature sensor that measures soil and environmental temperature. Accurate readings help understand crop growth conditions and prevent overheating of soil or robot electronics.



Figure 6.4: Temperature Sensor (DS18B20)

➤ **L298N Motor Driver**

As shown in the below figure7, Controls the DC motor by providing sufficient current and voltage. It enables forward and backward mechanism.

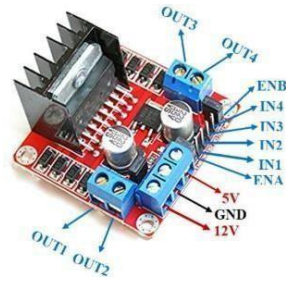


Figure 6.5: L298N Motor Driver

➤ Dual Shaft DC Motor

As shown in the below figure 8 Two or more motors are used to drive the wheels of the rocker-bogie mechanism. Provide the necessary torque to move on uneven ground.

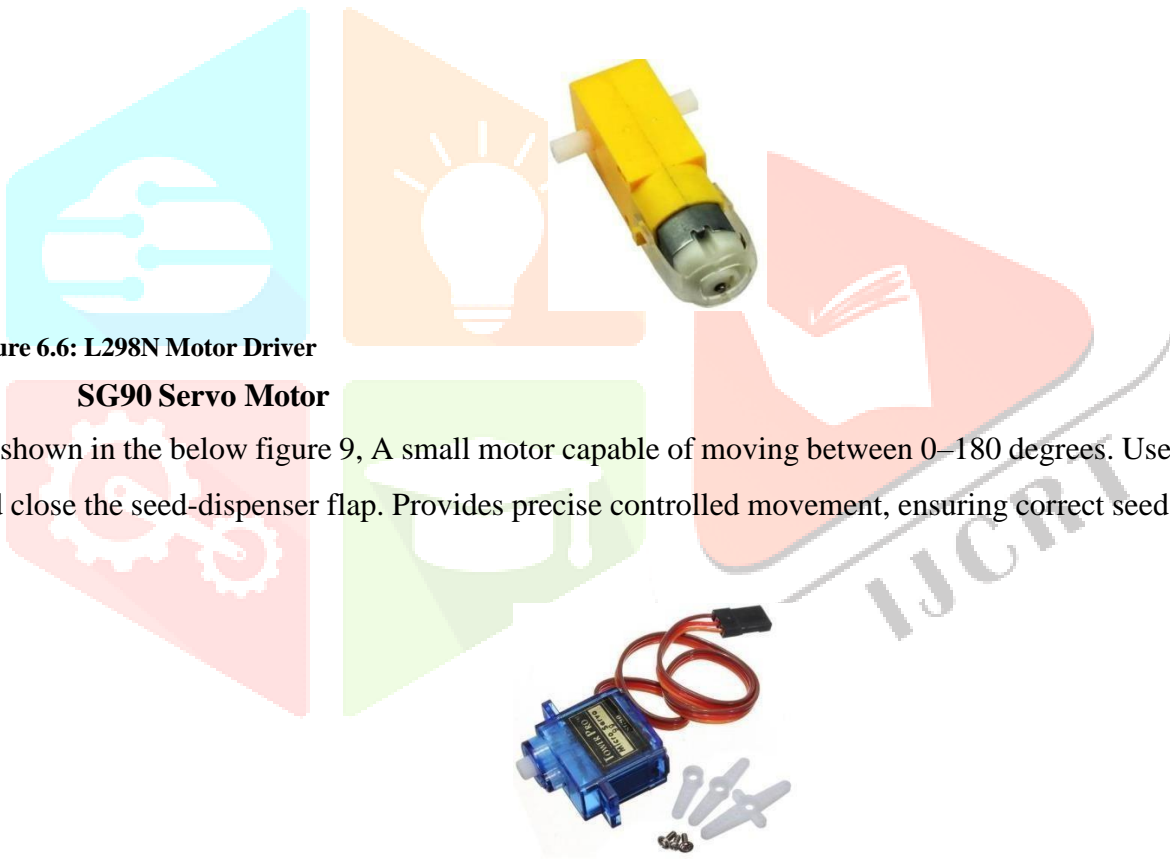


Figure 6.6: L298N Motor Driver

➤ SG90 Servo Motor

As shown in the below figure 9, A small motor capable of moving between 0–180 degrees. Used to open and close the seed-dispenser flap. Provides precise controlled movement, ensuring correct seed quantity.



Figure 6.7: SG90 Servo Motor

➤ Water Sprayer Motor

As shown in the below figure 10, Used for spraying water or pesticides. It pulls water from a container and releases it through a nozzle. Controlled through the ESP32 using a motor driver or relay module.



Figure 6.8: Water Sprayer Motor

➤ **Li-ion Battery**

As shown in the below figure 12, Supplies stable power to the ESP32, sensors, motors, and other hardware components, ensuring portable operation of the system.



Figure 6.9: Li-ion Battery

➤ **Wires and Connectors**

As shown in the below figure 12, Used for interconnecting all sensors, motors, and modules to the ESP32 and motor driver.



Figure 6.10: Wires and Connectors

6.2 Software Components

➤ **Arduino IDE**

Used to write, compile, and upload code to the ESP32. Supports libraries like WiFi, Servo, IoT Cloud, and sensor drivers. Allows serial monitoring for debugging.

➤ **Arduino IoT Cloud**

A cloud-based dashboard where widgets are created to display real-time sensor values and control actuators. The project uses:

- Moisture Display Widget
- Temperature Display Widget
- Motor Forward Control Button
- Seed Dispenser Button
- Sprayer Button
- Motor Backward Control Button
- Message Widget (Status updates)

➤ **IoT Communication Libraries**

ESP32 uses WiFi connection to send and receive data from the cloud. Libraries like Arduino IoT Cloud.h, WiFi.h, and Arduino Connection Handler.h manage this communication.

➤ **Cloud Dashboard Automation**

Allows the robot to automatically update soil data every few seconds and triggers actions when buttons are pressed. Enables remote farming operations from anywhere.

CHAPTER 7

RESULTS AND DISCUSSION

The system was tested under practical conditions to evaluate its performance and reliability. During operation, the ESP32 successfully established a connection with the Arduino IoT Cloud and maintained stable communication throughout the testing period. Sensor data from the soil moisture and temperature sensors were continuously monitored and accurately displayed on the IoT dashboard, providing real-time insights into environmental conditions.

The robot demonstrated effective mobility as shown in the figure 16, responding accurately to user commands sent from the dashboard. Forward and backward movements were smooth, and directional control was achieved efficiently using the motor drivers. The differential control of left and right motors enabled precise turning, allowing the robot to navigate the field without difficulty.



Figure 7.1: System Model

The seed dispensing mechanism functioned as expected, with the servo motor opening and closing the container accurately when triggered. This ensured proper distribution of seeds without wastage. Similarly, the water spraying system operated reliably, with the pump activating instantly upon command and delivering consistent water flow for irrigation.

The ESP32-CAM as shown in below figure17, module provided continuous live video streaming, allowing real-time monitoring of the robot's actions. The video feed was clear and enabled the user to visually confirm operations such as movement, seed dispensing, and spraying. In cases of temporary network interruptions, the ESP32 attempted automatic reconnection, ensuring minimal disruption in data transmission and control.

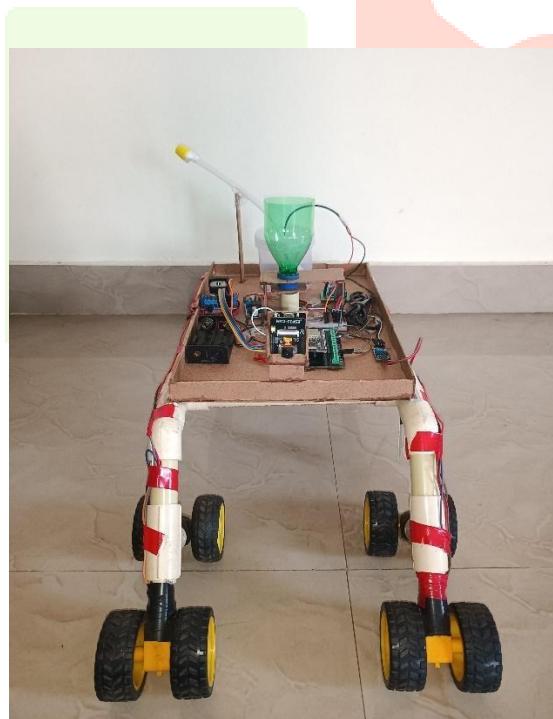


Figure 7.2: System Model

Overall, the system performed efficiently and demonstrated reliable integration of IoT, sensing, and automation technologies. The results confirm that the proposed system is capable of reducing manual labor while improving accuracy and monitoring in agricultural applications.

IoT Dashboard Interface and Control

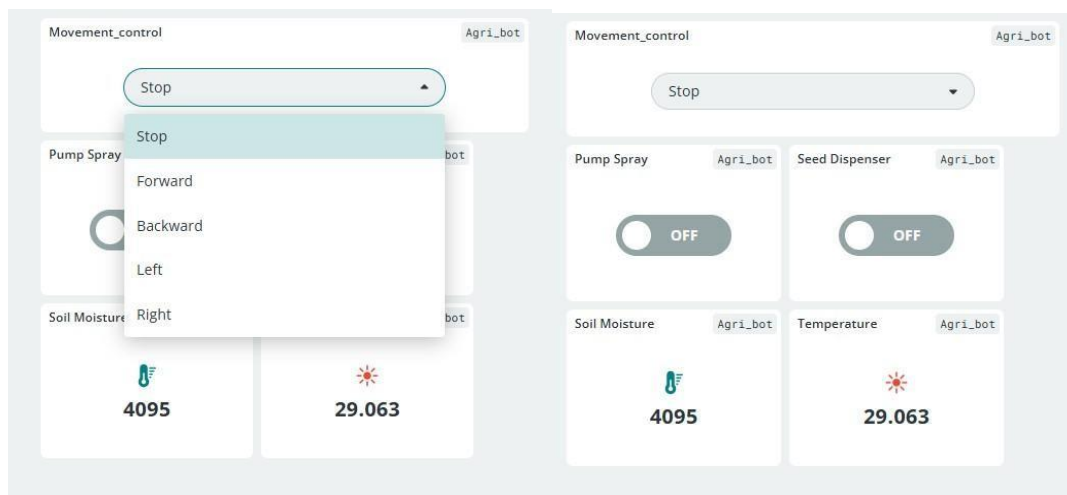


Figure 7.3: System Dashboard

The above dashboard figure 18, represents the Arduino IoT Cloud interface used to monitor and control the agricultural robot in real time, displaying sensor data such as soil moisture and temperature along with control options for robot movement, seed dispensing, and water spraying. This user-friendly interface allows the farmer to remotely operate the system efficiently and make quick decisions based on live data. The dashboard also provides instant visual feedback through toggle switches and control menus, ensuring that the user can easily understand the current state of the system, while the movement control dropdown enables precise navigation of the robot in different directions. Furthermore, the continuous updating of sensor values helps in making timely decisions for irrigation and seeding, thereby enhancing overall farming efficiency.

The below table 1, represents the real-time performance of the system by showing the sensor readings, robot actions, and corresponding outputs on the IoT dashboard. It clearly indicates how each component responds to user commands and environmental conditions. This helps in verifying the accuracy, reliability, and overall functionality of the smart agricultural robot.

Parameter	Component Used	Observed Value	Cloud Display / Output
Soil Moisture	Soil Moisture Sensor	30% – 80% (varies with soil condition)	Real-time value displayed
Temperature	Temperature Sensor	25°C – 35°C	Real-time value displayed
Robot Movement	DC Motors + Drivers	Forward, Backward, Left, Right movement	Controlled via dashboard buttons
Seed Dispensing	Servo Motor	Opens and closes seed container	“Seeds Dispensed” message
Water Spraying	Pump Motor	ON/OFF water spraying	“Spraying Completed” message
Live Monitoring	ESP32-CAM	Continuous video streaming	Live video feed

Network Connection	WiFi (ESP32)	Auto reconnect on disconnection	Connection status updates
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Table 1: System Parameters and Observed Outputs

The above table represents the real-time performance of the system by showing the sensor readings, robot actions, and corresponding outputs on the IoT dashboard. It clearly indicates how each component responds to user commands and environmental conditions. This helps in verifying the accuracy, reliability, and overall functionality of the smart agricultural robot.

CHAPTER 8

OBJECTIVES ACCOMPLISHED

The primary objective of the project, which was to design and develop a smart agricultural robot using IoT technology, was successfully achieved. The system was able to monitor important environmental parameters such as soil moisture and temperature in real time using appropriate sensors integrated with the ESP32 microcontroller. The collected data was effectively transmitted to the Arduino IoT Cloud, allowing the user to access and analyze field conditions remotely.

Another key objective was to enable remote control and automation of farming activities, which was accomplished through the IoT dashboard interface. The robot responded accurately to user commands for movement, seed dispensing, and water spraying. The integration of motor drivers, servo motor, and pump ensured smooth operation of all mechanical functions, thereby reducing manual effort and improving operational efficiency.

Finally, the objective of providing real-time visual monitoring was achieved using the ESP32-CAM module. The system successfully streamed live video, enabling the user to observe the robot's activities remotely. Overall, the project met all its intended goals by combining sensing, automation, and IoT-based control into a single efficient system, making it a reliable solution for smart agriculture applications.

CHAPTER 9

COST OF THE PROJECT

The total estimated budget for the proposed health-monitoring system has been calculated by considering all essential electronic components and supporting materials. The following table provides a detailed cost breakdown for each item used in the project as shown in the below table 1

Component	Cost (INR)
ESP32	500
Esp32 cam module	1200
Soil Moisture Sensor	200
Temperature Sensor	150
L298N Motor Driver	200
DC Motor	500
SG90 Servo	100
Spraying Pump	250
Li-ion Battery	800
Motor Driver	200
Miscellaneous	2000
Total	6,100

Table 2: Cost of the Project

CHAPTER 10 ACTION PLAN

The project will be executed in a structured and time-bound manner to ensure systematic development and timely completion. The following action plan outlines the major phases of work along with their respective durations as shown in the below table 2.

Phase	Task	Duration
1	Component Collection	1 week
2	Sensor Interfacing & Testing	1 week
3	IoT Dashboard Setup	1 week
4	Seed Dispenser & Sprayer Integration	2 weeks
5	Mechanical Assembly	1 week
6	Esp32 cam module setup	2 weeks
7	Documentation & Report preparation	2 weeks

Table 2: Action Plan

CHAPTER 11

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