Indian Journal of Modern Research and Reviews

This Journal is a member of the *'Committee on Publication Ethics'*

Online ISSN:2584-184X

Research Paper

AI Based Smart Agriculture Robot

Mohd Salim Jan[1*], Tsewang Samtan[2], Mohd Arif[3], Rigzin Angmo[4], Sonam Chuskit[5], Jigmeth Choskit[6], Deachan Dolker[7], Phuntsog Toldan[8]

[1,2,3,4,5,6,7,8] Department of NIELIT, Ministry of Electronic and Information Technology, Leh, India

Corresponding Author: ***Mohd Salim Jan**

DOI: https://doi.org/10.5281/zenodo.14990234

ABSTRACT

Agriculture is a vital part of the economy in India, and in Ladakh, it presents a unique and challenging endeavor because of its high-altitude, arid climate, and limited rainfall. Agriculture in Ladakh is important but faces challenges due to lack of innovation. We have, therefore, developed an agricultural robot that will help automate various farming tasks, thus reducing labor and increasing efficiency. This agricultural robot is to enhance the agricultural operations such as soil analysis, diagnosis of plant, crop recommendations, spraying of water/pesticides, detection of objects using Raspberry Pi (master) that handles all the heavy functions, such as object detection, while the Arduino (2 slave) receives and sends signals from the sensor and monitoring of soil moisture and humidity without harming soil fertility. In addition, it also helps protect workers from dangerous insects and here we use a lithium-ion battery that is fully coated with thermal insulation to protect it from cold temperature technology controls the robot and feeds it with real-time AI insights, leading to more informed decision making and efficiency. A local Ladakhi voice assistant lets the farmers interact through the device in their first language so they can easily associate themselves with it. We have designed this voice assistant using Google Translator, pyttsx3, Speech recognition and Google Search to answer the farmer's queries and provide valuable information in a simple, easily accessible manner.

Manuscript Info.

- ✓ **ISSN No:** 2584-184X
- ✓ **Received:** 15-01-2025
- ✓ **Accepted:** 13-02-2025
- ✓ **Published:** 25-02-2025
- ✓ **MRR:3(2):**2025;59-74

- ✓ **Peer Review Process:** Yes
- ✓ **Plagiarism Checked:** Yes

How To Cite

Jan MS, Samtan T, Arif M, Angmo R, Chuskit S, Choskit J, Dolker D, Toldan P. AI-based smart agriculture robot. Indian J Mod Res Rev. 2025;3(2):59-74.

KEYWORDS: Agriculture, AI, IOT, Spraying water, Raspberry pi, humidity.

1. INTRODUCTION

India has always been an agricultural country, which mainly depends on natural resources. Farming is the main part of India's economy.Mainly we are focus on ladakh agriculture because the region is high altitude,arid climate and limited rainfall. Agricultural robots are a growing trend because they provide major advantages to the agriculture industry. These robots are designed to perform a lot of tasks, such as spraying crops, checking the moisture in the soil, detection of disease, and others

while reducing labor costs and maximizing efficiency. Perhaps the main advantage of farm robots would be that they can work with all-around clocking systems regardless of weather conditions, thus significantly minimizing downtime and maximizing productivity. These technologies can enhance crop yields while simultaneously decreasing the use of destructive pesticides and herbicides, as they can target specific areas in the field with high accuracy. Agricultural machinery such as water sprinklers (WS) and pesticide sprayers (PS) is becoming popular among the agricultural community. Robotics in agriculture is a promising technology that can provide efficient and reliable solutions for the modernization of various sectors. Agricultural robots are generally equipped with various sensors and cameras that help them collect data on soil conditions, crop health, and other important parameters. There are two main conditions on which the requirement for mechanization in the agricultural field is based. The first is that technology in agriculture are advantageous to both the farmers and the nation. A local Ladakhi voice assistant lets the farmers interact through the device in their first language, so they can easily associate themselves with it. The AI Robotic Voice Assistant promotes sustainable farming practices by offering efficient solutions that save water, reduce labor costs, and reduce the environmental footprint. In other words, it helps farmers to farm more intelligently rather than harder, thereby introducing a new standard of precision and convenience.

2. LITERATURE REVIEW

In this article [1], the author designs, develops, and creates a robot that can sow seed, plough, and apply pesticides, spraying is powered by solar energy. The robot employs several techniques to track various activities in the farming process, including soil type, nutrient levels in the soil, monitoring soil moisture by using a sensor like a soil moisture sensor, pH sensor. In this article [2], it highlights the importance of soil pH for crop growth and nutrient availability. In this article [3], the authors discuss advancements in IoT-based agricultural systems, focusing on automated irrigation and soil monitoring. It highlights research using IoT devices like Arduino and GSM networks to track temperature, pH, and soil moisture in real time.

In this article [4], the design of an FPGA-based soil irrigation robot, highlighting key concepts in water management and automation for agriculture. Soil moisture sensors like the FC-28 are crucial for efficient irrigation by measuring water content in soil. This helps optimize water usage, improving crop yield and conserving water resources. The L298N motor driver is used to control DC motors, essential for movement and operation of irrigation pumps, offering efficient power and direction control. The literature suggests that FPGA-based smart irrigation systems improve water conservation, automation, and crop yield. In this article [5], the paper presents a plant irrigation robot that autonomously irrigates fields with a single sprinkler and water tank. It highlights key advancements in automation and robotics for agriculture. In conclusion, robotics and automation in irrigation provide significant benefits, including water conservation, reduced labour, and cost savings. In this article [6], Soil moisture and pH are vital for crop growth, and technological advancements have improved their monitoring and control. Soil pH impacts plant health and yield. In conclusion, automated systems for soil moisture and pH regulation improve crop yields and sustainability, with future advancements expected in sensors and real-time monitoring.

3. OBJECTIVES

1. Developed an AI command-based agricultural multitasking system by Raspberry pi to perform agricultural tasks for farming operations.
2. To facilitate agriculture in harsh regions like Ladakh.
3. Robots use modern technology, including robotics, artificial intelligence (AI), sensors, technology, to perform various tasks like object detection, soil moisture sensing, PH level monitoring, water sprinkler control, and voice command Robot-based control.
4. Improving agricultural productivity by minimizing labour costs and human effort.
5. AI-based object detection using a Raspberry pi camera able to detect the obstacle.
6. Soil moisture sensing to keep track of the soil's moisture content, the robot will use soil moisture sensors which are connected to the Raspberry Pi.
7. PH Monitoring: The Raspberry Pi will use a pH sensor to determine how acidic or alkaline the soil is.
8. Water sprinkler: Depending on the sensor readings, the Raspberry Pi will share with the sprinkler hardware to turn on or off the sprinklers.
9. Voice command Robot control: The robot will take voice orders from the farmer using speech recognition software and with basic voice commands like "Forward, Backward," "Check soil moisture," or "Stop robot," farmers may operate the robot.

4. Problem Statement

Conventional methods of farming lead to in problems such as overuse of water, uneven fertilizer application, a lack of soil data collection, decreased production, and higher costs. The purpose of an Argo-robot, which was created especially for agriculture, is to reduce the amount of labor that farmers need to do in the field. the younger generation are less likely to choose farming as a career, and the agriculture sector is facing a skilled labor shortage. Farmers find it challenging to locate sufficient workers to meet their needs as a result of aged farm populations and an overall decline in interest in agricultural work. By using AI voice command-based agriculture robots, many problems can be resolved, such as: -

Lack of Workers and Changing Work Quality: Finding and managing manual labour in agriculture is getting harder, particularly in rural or isolated places. Watering, crop monitoring, are examples of tasks that need a lot of human labour and may not be reliable or effective. By providing automation, the robot minimizes the dependence on humans and provides consistent operation.

Monitoring of the Environment and Soil Health: Since moisture content and pH levels are crucial for plant growth, many farmers do not have simple access to real-time data on soil health. Farmers face applying improper nutrients or fertilizers or losing out on chances that will improve the quality of their soil if they lack adequate monitoring. By providing real-time monitoring, the robot will notify farmers when soil conditions require attention.

Crop management with limited precision: Time-consuming inspections and the use of pesticides are frequently necessary to detect and treat problems such as disease, insect pests, and lack of nutrition in crops. These positions are dependent on inconsistency and human error in the absence of automation.

Use and Easy access: Many farmers, particularly those in distant areas, are unable to use traditional agricultural robots due to their high technical skill requirements. A voice-activated system would eliminate the need for technical expertise by enabling farmers to communicate with the robot in an easy-to-understand way.

5. METHODOLOGY

The methodology of the entire system is described in this section. The robotic system has consisted of two parts:

- Robotic Car and Automation System
- Sensors and IOT Part

The robot car is designed to move around and can be controlled using voice assistants. It integrates sensors and IoT modules, making it ideal for smart farming operations. All control systems and sensors are installed on the vehicle. The body is made of metal and uses a DC gear motor to drive the vehicle. The battery supplies power to the motor. While servo motors are used to control the wheels. This ensures there is enough torque for precise speed and position. Moreover, the robot car has many advanced components such as humidity and temperature sensors. Moisture sensors, pH sensors, and other cutting-edge modules. Humidity and temperature sensors help monitor environmental conditions to optimize crop growth. The moisture sensor estimates the water content in the soil. This will ensure that the plants receive adequate moisture. Overall, this robot vehicle offers a comprehensive solution for modern agricultural needs. By combining innovation with practical functionality.

DESIGN OF CHASSIS

The chassis is the fundamental frame of a robot, all other parts are fixed to it. It greatly contributes to the structural stability and is the basis for attaching major systems, such as the suspension system, steering system, and seating arrangement of the occupants or working modules.

This chassis is made from a metallic material that is known for strength and durability. The construction process includes arc welding, a reliable method that ensures the joints are robust and capable of withstanding different stresses during operation. The dimensions of the chassis are approximately 30 cm × 40 cm, with a height of 15 cm, offering a compact yet stable platform for the robot. The choice of these dimensions was made to achieve an optimal balance between size, weight, and functionality.

1) **Suspension System**: Four spring suspensions are integrated into the design for smooth performance of the robot over different terrains. Springs are essential for dampening shocks and vibrations from irregular terrain, maintaining the stability of the chassis, and ensuring no damage to sensitive parts in the interior. Not only does the suspension system improve the robot's ability to traverse rough terrains but also ensures consistent performance since the vehicle is kept well balanced during motion. The springs are located at four corners of the chassis to ensure balanced weight, relieving mechanical stress on the framework.

2) **Steering System**: The steering mechanism has been designed meticulously using on shape, this mechanism allows the robot to turn left and right smoothly. For steering, a 60 kg servo motor is used to provide the required torque and precision for turning the wheels. In this setup, the servo motor is a critical component since it offers responsive and accurate steering control under varied loads or conditions. For better performance of the steering system, the servo motor is accompanied by an inclined spring suspension. This suspension design is made to counteract and absorb the inclined forces that happen in the turning makeovers. It is included to prevent over- straining the chassis and maintain the balance of the robot when it is turning at various speeds or on sloped surfaces.

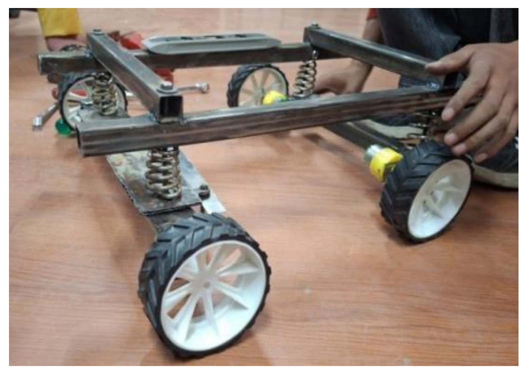


Fig. 1: Chassis

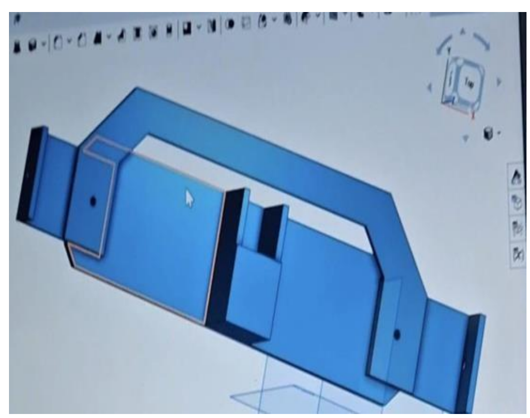
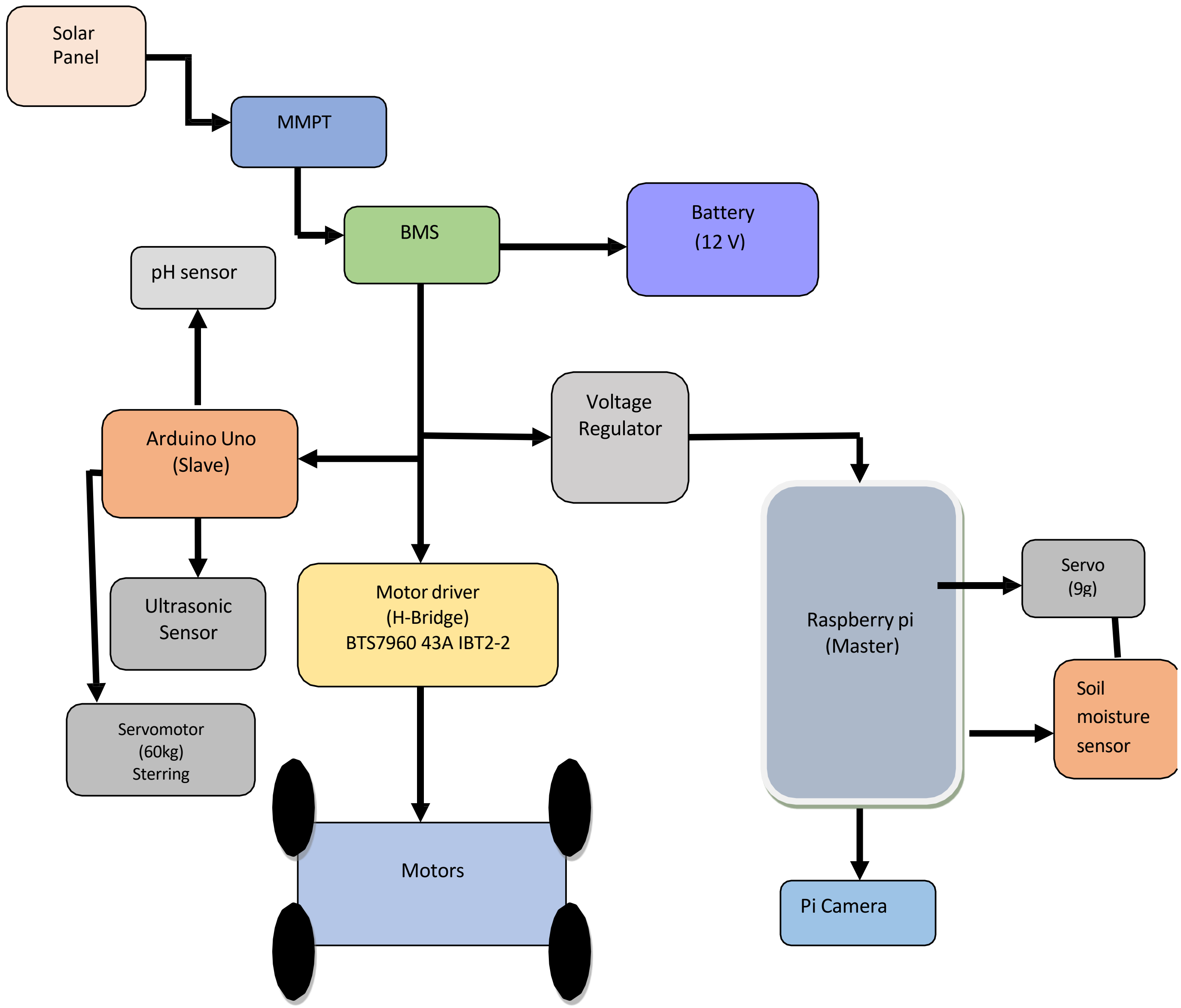


Fig. 2: Steering Mechanism

Proposed Architecture



FLOW CHART

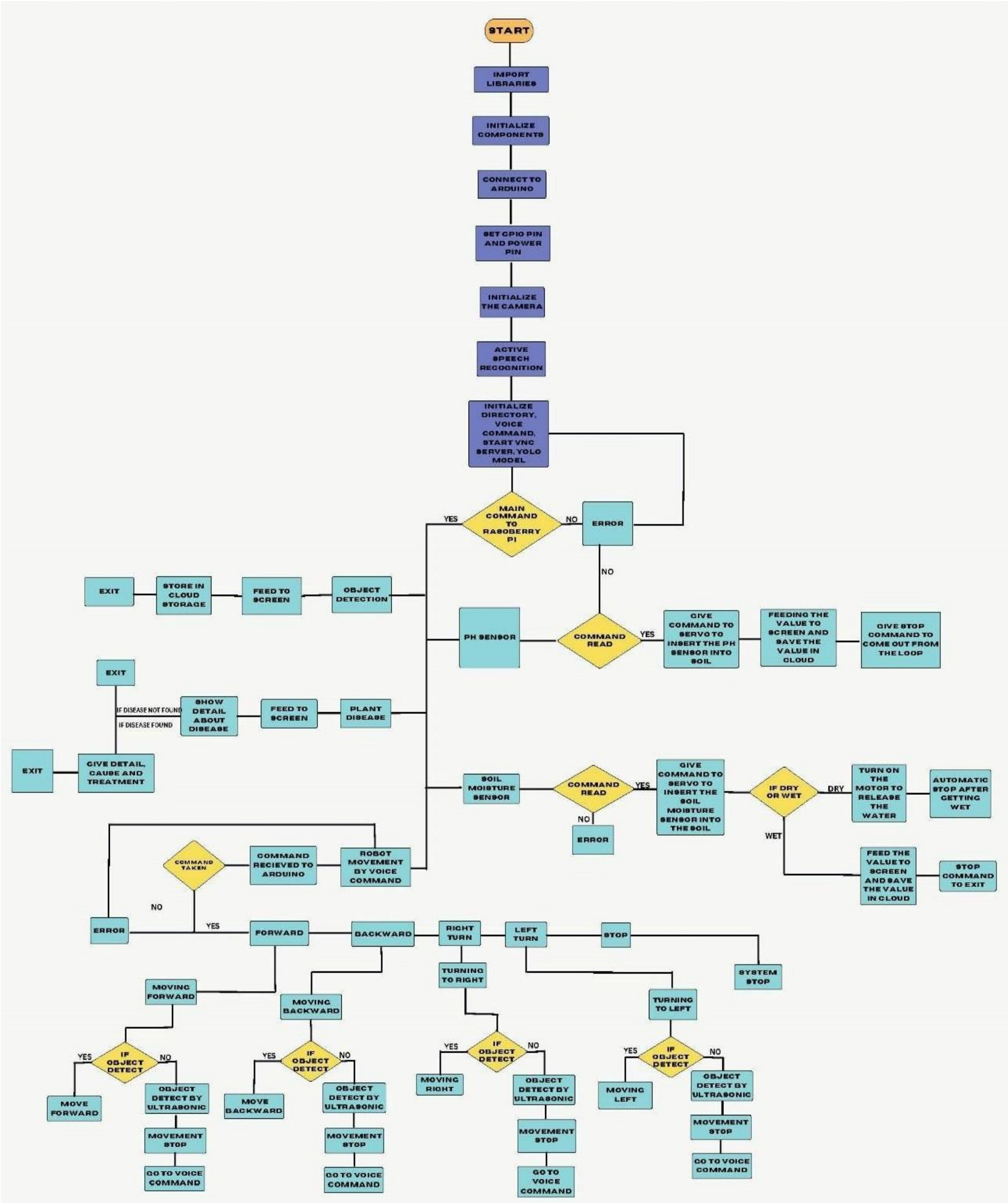

START
IMPORT LIBRARIES
INITIALIZE COMPONENTS
CONNECT TO ARDUINO
SET GPIO PIN AND POWER PIN
INITIALIZE THE CAMERA
ACTIVE SPEECH RECOGNITION
INITIALIZE DIRECTORY, VOICE COMMAND, START VNC SERVER, YOLO MODEL
MAIN COMMAND TO RASOBERRY PI
YES
NO
ERROR
NO
EXIT
STORE IN CLOUD STORAGE
FEED TO SCREEN
OBJECT DETECTION
PH SENSOR
COMMAND READ
YES
GIVE COMMAND TO SERVO TO INSERT THE PH SENSOR INTO SOIL
FEEDING THE VALUE TO SCREEN AND SAVE THE VALUE IN CLOUD
GIVE STOP COMMAND TO COME OUT FROM THE LOOP
EXIT
IF DISEASE NOT FOUND
IF DISEASE FOUND
SHOW DETAIL ABOUT DISEASE
FEED TO SCREEN
PLANT DISEASE
EXIT
GIVE DETAIL, CAUSE AND TREATMENT
SOIL MOISTURE SENSOR
COMMAND READ
YES
NO
ERROR
GIVE COMMAND TO SERVO TO INSERT THE SOIL MOISTURE SENSOR INTO THE SOIL
IF DRY OR WET
DRY
TURN ON THE MOTOR TO RELEASE THE WATER
AUTOMATIC STOP AFTER GETTING WET
WET
FEED THE VALUE TO SCREEN AND SAVE THE VALUE IN CLOUD
STOP COMMAND TO EXIT
COMMAND TAKEN
COMMAND RECIEVED TO ARDUINO
ROBOT MOVEMENT BY VOICE COMMAND
NO
ERROR
YES
FORWARD
BACKWARD
RIGHT TURN
LEFT TURN
STOP
SYSTEM STOP
MOVING FORWARD
MOVING BACKWARD
TURNING TO RIGHT
TURNING TO LEFT
IF OBJECT DETECT
YES
NO
MOVE FORWARD
OBJECT DETECT BY ULTRASONIC
MOVEMENT STOP
GO TO VOICE COMMAND
MOVE BACKWARD
MOVING RIGHT
MOVING LEFT

Table 1: Components and Specification

COMPONENTS	SPECIFICATION	
1. Raspberry pi 4B	a. Processor	ARM64Quad-Core
	b. Ram	LPDDR4-3200 8GB
	c. Power consumption	2.5 A
	d. Storage	512GB micro-SD Card
	e. Operating system	Raspberry pi OS
2. Arduino Uno	a. Microcontroller	AT mega168
	b. Operating Voltage	5V
	c. Input Voltage (recommended)	7-12V
	d. Input Voltage(limit)	6-20V
	e. Digital I/O Pins	14
	f. Analog Input Pins	6
	g. DC Current Per I/0 Pin	40mA
	h. DC Current for 3.3V Pin	50mA
	i. Flash memory	32kb
3. Soil moisture Sensor	a. Operating voltage	+5V
	b. Output voltage signal	0’’’4.2V
	c. Current	35MA
4. Ultrasonic sensor	a. Technology used	Transmitter and Receiver
	b. Operating voltage	5V
	c. Detection range	2cm to 400cm
	d. Measuring angle	30°
	e. Operating current	<15mA
5. pH Sensor	a. Accuracy	pH ±0.1(25°C)
	b. Response time	≤1 min
	c. Power supply	5V
	d. Measuring range	pH 0-14
6. Pi Camera	a. Resolution	5 megapixels
	b. Video mode	1080P30,720P60
	c. Sensor	Omni Vision OV5647
	d. Sensor Resolution	2592 x 1944 pixels
7. Motor Driver (H -Bridge) BTS7960 43A IBT2-2	a. Operating Voltage	6V-27V DC
	b. Max. output current	43A
	c. Logic level Voltage	3.3V or 5V
	d. PWM input frequency	Up to 25 kHz
	e. Threshold	~43A
8. Motors	a. Power supply	12V DC
	b. RPM	500
	c. Torque	1kg-cm
	d. Load current	up to 7.5A(max)
9. Servomotor (60kg)	a. Voltage	6-8.4V,
	b. Angle	180°/270°
	c. Driving	PWM
10. Servomotor (9gm)	a. Voltage	4.8-6V
	b. Angle	180°
	c. Driving	PWM
11. LCD	a. Size	7 inches
	b. Resolution	1024 x600
	c. Display Port	HDMI
	d. Viewing angle	170°
	e. Consumption	Low power
12. Muse Speaker	a. Polar pattern	Omnidirectional
	b. Audio sensitivity	85db
	c. Inbuilt mike	Upto5-6m

A. SOLAR PANEL

Being eco-friendly and a renewable source of energy, these technologies, like solar panels, have high usage because they form a reliable source of energy for various applications and uses. With the integration of solar panels in the robot, it allows them to utilize the energy from sun to recharge the batteries, increase their operating range or power add-on equipment in a non-consumptive way and hence reduces dependency on other sources of recharging.

Power-120w Current-10A Voltage-12V

Type - Thin-film solar panel. The name 'thin film' clearly suggests that in comparison to crystalline silicon, these panels are significantly thinner, and hence flexible, and lighter – ideal for use in curvy surfaces, or areas where larger solar panels cannot be used.

The lightweight nature of thin-film panels makes them easily integrated into a variety of vehicle designs. This flexibility would allow placing it in non-traditional areas to acquire the maximum amount of solar gain without adding too much weight. Thin-film solar panels can be integrated in a manner that would make it match with the vehicle aesthetics and look good apart from its functionality. This is very relevant for consumer markets where design becomes one of the major parameters while making any purchase decision. Crystalline silicon panels are more expensive to make and, consequently, purchase than most thin-film technologies. This can also reflect the overall cost of incorporating solar solutions into vehicles. Some thin-film solar panels are very effective under conditions of low light or diffuse light, in that they are better at electricity generation in overcast or foggy conditions. That helps mostly with sites getting a small number of cloudy days yearly.

B. MPPT (maximum power point tracking) Maximum Power Point Tracking (MPPT) is an algorithm in charge controllers which maximizes the available power drawn from a photovoltaic (PV) module under certain conditions. The voltage at which the PV module generates maximum power is called the maximum power voltage. Maximum power output varies with solar radiation, ambient temperature, and solar cell temperature. This kind of MPPT continuously measures the PV module output, compares it to battery voltage, and determines the peak power a PV module can produce to recharge a battery. Then the unit translates the power into an optimal voltage to maximize the charging current into the battery. Along with charging the battery, MPPT can support direct power supply to the connected DC load on top of the battery.

a) **Solar Power charge time calculation using MPPT**

Battery voltage=12.6V
Battery Ampere=25A
Battery Depth of discharge (DOD)
Assume to be 100%
Solar panel (W)=120W
Solar panel current=120w ÷ 12V
=10A

$$\text{Charging time} = \frac{\text{BATTERY CURRENT CAPACITY}}{\text{SOLAR PANEL CAPACITY}}$$

$$\frac{25A}{10A}$$

= 2.5hr
Total time taken for full charging =2.5hr

D. BATTER (LITHIUM ION)

Lithium-ion battery is a rechargeable battery that stores energy by reversibly intercalating Li+ ions into electronically conducting substances. Li-ion batteries are dominantly used in electrical energy storage systems because of several reasons: They hold the capability to store more energy in a unit volume to achieve long distances while driving with additional energy without the bulk considerably increasing. Another benefit of lithium-ion batteries is the lifespan or the relative count of charge- discharge cycles it can endure before its capacity is degraded, hence serving the car for a considerable period. The factors include charging times which are normally faster than those used in charging of lead-acid batteries, low maintenance costs which add to convenience. Besides, their ability to deliver power and efficiency is better; they provide high acceleration and optimum energy consumption. In the early years, they may be costly but present improvements in technology have ensured that their costs are gradually being offset while retaining these benefits. All these features make the lithium-ion battery as most viable for use in the new generation automobiles due to its efficiency, length of life and the productivity in comparison with lead-acid battery. The separator prevents the negative electrode, known as the anode when the cell discharges, from shorting with the positive electrode called the cathode when its cell discharges. The current collectors, which are two pieces of metal connecting the electrodes to the powered circuit, have the positive and negative electrodes swap the Electrochemical roles (anode and cathode) when the cell is charged. Despite this, in discussions of battery design the negative electrode of a rechargeable cell is often just called "the anode" and the positive electrode "the cathode".
The design of the battery pack gives an output of 12.6V and 25A with the cells arranged in 3 in series and 5 parallel. which reduces capacity and raises the risk of failure, just like low AC rates do.

2) Temperature sensor in Bms

To detect the temperature of the battery cells and pack, the BMS system uses a variety of temperature sensors, the most popular of which are thermostats. The BMS receives real-time data from these sensors and uses it to regulate all aspects of the battery, including charging, discharging, and cooling.
Sensor Location: To offer near real-time coverage, sensors are typically placed close to the cells, modules, and other important system components. Duplicate or backup sensors can be added to safety- critical applications to give an extra degree of protection, guaranteeing that the system is still safe even in the event of a primary sensor failure. This guarantees thorough covering and reduces the possibility of thermal.

Figure 3: Lithium-ion battery

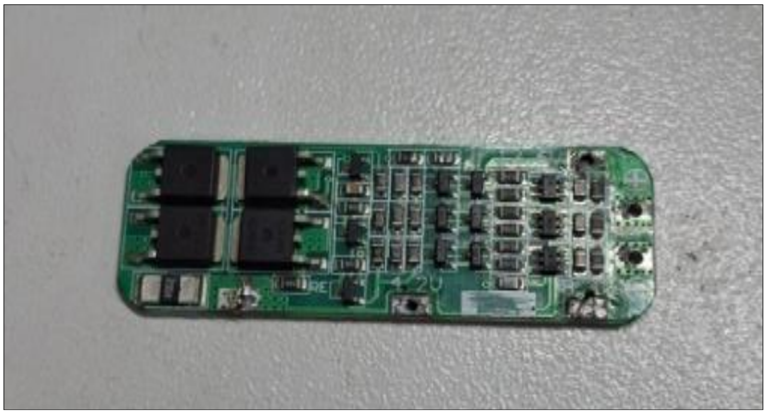


Figure 4: BMS

D.BATTERY MANAGEMENT SYSTEM

A Battery Management System (BMS) is an electronic control system that monitors, manages, and protects rechargeable batteries. It ensures the battery operates safely, efficiently, and within optimal performance parameters. The main functions of a BMS are as follows:

Voltage Monitoring

Check the voltage of each cell every day to prevent the battery from becoming overcharged or over discharged, as these conditions will permanently harm the battery.

1) **Temperature monitoring**: regulating the battery pack's temperature and implementing safeguards against thermal runaway, or overheating of the pack.

a) **Optimal Operating Temperature**: Each battery has a certain temperature range between 20°C and 40°C where it operates at its best. Any departure from this current range compromises the cells' capacity and efficiency and speeds up their deterioration.

b) **Impact on Charging**: Because greater temperatures cause unintended chemical reactions and deterioration, charging batteries at higher temperatures is not recommended. Charging at extremely low temperatures causes lithium plating,

Battery calculation

Single Battery calculations =3.7V,
5A Li-ion Total Battery in series=3
Battery Parallel connected =5,
Total number of cells=3×5=15 cells
Voltage calculation 4.2×3=12.6V
Ampere calculation 5×5=25A

Table 2: Specification of BMS

Cell configuration	**3 series cells (3S)**
Rated current	25A
Peak current	50A
Maximum Voltage	4.2V
Minimum Voltage	3.0V
Overvoltage Protection	4.2V±0.05V
Under voltage Protection	3.0V±0.05V
Weight	13g

Table 3: Specification of Lithium-Ion Battery

Nominal voltage	**3.7V**
Nominal capacity	5000mAh
Internal impedance	150-250mΩ
Discharge cut-off voltage	2.5V
Max charge voltage	4.2V
Rapid charge current	1.3A
Standard charge current	0.52A
Standard discharge current	0.52A
Max pulse discharge current	2.6A
Weight	46.5±1g
Storage temperature	Charge:0-45 Discharge: -20 -60
Operating temperature	During 1 month: -5-35, During 2 months:0-35°C

For this reason, keeping the pH range of the soil within the ideal range is essential for plant growth and nutrient availability.

a. Soil pH and Microbial Activity

Microbial activity is also significantly influenced by the pH of the soil. Because they improve soil structure, fix nitrogen, and break down organic materials, microorganisms are vital to soil health. Most microorganisms thrive in the pH range of 6.0 to 7.5. Microbial activity declines with excessively high or low soil pH, which lowers soil health.

b) Soil pH and Soil Structure

Soil structure is also influenced by soil pH. The arrangement of soil particles and the gaps between them are referred to as soil structure. For soil structure, a pH range of 6.0 to 7.0 is ideal. Soil erosion and decreased water-holding capacity can result from a damaged soil structure caused by an excessively high or low pH.

c) Soil Ph Sensor

A soil pH sensor is a device that can measure soil pH values. It measures the concentration of hydrogen ions ($H+$) in the soil by inserting electrodes into the soil. The concentration of hydrogen ions is directly related to the pH value, which determines the soil's acidity or alkalinity.

d) Working principles of soil ph sensors

The working principle of a soil pH sensor is based on electrochemical reactions. The working principles of soil pH sensors mainly involve two processes: electrode potential measurement and signal conversion.

e) Electrode potential measurement

The sensor consists of two electrodes: a reference electrode and a sensing electrode. The reference electrode maintains a constant potential relative to the sensing electrode. When the sensor is placed in a soil solution, there will be a potential difference between the two electrodes. This potential difference is directly proportional to the concentration of hydrogen ions in the soil solution, which represents the pH value.

f. Sensors Use

1) Soil pH

The acidic nature or alkaline nature of a solution is determined by its pH. Typically, the pH scale has a range of 0-14. The soils were classified based on their pH values, which are listed in Table 2. The pH of the soil significantly affects the nutrients that are available to plants. Plants can most readily absorb nutrients like nitrogen, phosphate, and potassium when the pH of the soil is between 6.0 and 7.0. These nutrients become less available when the pH of the soil is too high or too low, and plants may have nutrient shortages. For instance, manganese and aluminum become more soluble in too-low pH soil, which can be harmful to plants. On the other hand, plants have less access to iron, zinc, and other micronutrients when the pH of the soil is too high. MPPT is very effective under the following conditions:

2. **Cold weather, cloudy, or hazy days**
   PV modules perform better at low temperatures. MPPT makes sure that maximum available power is extracted from the PV modules under such conditions.
3. **Deeply discharged batteries**
   If the state of charge of a battery is low, more current can be drawn by MPPT from the PV module to recharge the battery effectively. MPPT significantly improves the charging process, which means that solar energy can be stored efficiently in the battery. This is particularly beneficial for maintaining the health of the battery and prolonging its lifespan, making it an essential component for solar-powered systems such as vehicles.

There are two methods to measure the pH of water.

1. First method is costly and requires a high-end pH sensor to measure it directly.
2. The second method is based on the conductivity of soil. Capacitor plates are inserted in the soil and the voltage

generated between them is measured, and through calibration, the pH from the conductivity can be determined. The acidic solution means more H+ ions, the basic means more OH- ions. The mobility of H+ ions is greater than the mobility of OH- ions. This mobility also plays a very important factor in the calibration of pH. The concentration of H+ ions can be determined by calibration. This will give pH value of soil.

Figure 6: Circuit diagram of soil pH sensor

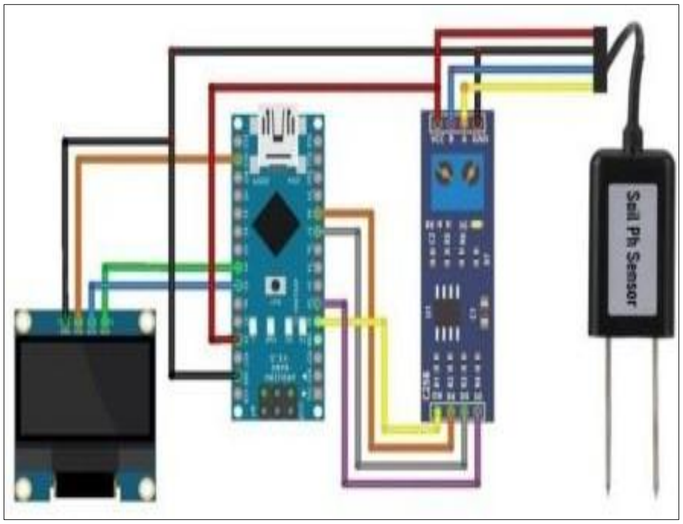


Table 4: pH value range

S. No.	Chemical characteristics of the soil	pH value
1.	Very Acidic	<4.5
2.	Strongly Acidic	4.6-5.4
3.	Slightly Acidic	5.5-6.5
4.	Neutral	6.6-7.2
5.	Slightly Alkalized	7.3-8.4
6.	Strongly Alkalized	8.6-9.0
7.	Very Strongly Alkalized	>9

Table 5: Impact of Soil pH on Nutrient Availability and Crop Growth

Nutrient	Optimal pH range	Availability at low pH	Availability at High pH	Impact on crop growth
Nitrogen (N)	6.0 – 7.5	Reduced nitrification, lower nitrate formation	Reduced ammonium solubility	Essential for growth and development; deficiency leads to stunted growth and yellowing of leaves
Phosphorus (P)	6.0 – 7.0	Forms insoluble compounds with iron and aluminum	Forms insoluble compounds with calcium	Crucial for energy transfer, photosynthesis, and nucleic acids; deficiency causes poor root development and purple leaves
Potassium (K)	5.5 - 8.0	Leaching in acidic soils	Reduced availability due to competition with other cations	Vital for enzyme activation, osmoregulation, and stress resistance; deficiency results in weak stems and leaf chlorosis
Iron (Fe)	4.0 – 6.5	More soluble, readily available	Forms insoluble hydroxides and carbonates	Important for chlorophyll synthesis and electron transport; deficiency causes interveinal chlorosis in young leaves
Manganese (Mn)	5.0 – 6.5	More soluble, readily available	Forms insoluble compounds	Necessary for enzyme function and photosynthesis; deficiency leads to interveinal chlorosis and necrotic spots
Zinc (Zn)	5.0 – 7.0	More soluble, readily available	Forms insoluble compounds	Critical for enzyme activation and protein synthesis; deficiency results in stunted growth and malformed leaves
Copper (Cu)	5.0 – 7.0	More soluble, readily available	Forms insoluble compounds	Required for lignin synthesis and enzyme function; deficiency causes dieback of stems and leaf tips
Boron (B)	5.0 – 7.0	More soluble, but potential toxicity	Reduced availability	Essential for cell wall formation and reproductive development; deficiency leads to brittle stems and poor fruit set

Figure 6: Coding

```
#include <SoftwareSerial.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>

#define RE 8
#define DE 7
const byte ph[] = {0x01, 0x03, 0x00, 0x00, 0x00, 0x01, 0x84, 0x0A};
byte values[11];
SoftwareSerial mod(2, 3);

#define SCREEN_WIDTH 128  // OLED display width, in pixels
#define SCREEN_HEIGHT 64  // OLED display height, in pixels
#define OLED_RESET    -1  // Reset pin # (or -1 if sharing reset pin)
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);


void setup()
{
  Serial.begin(9600);
  mod.begin(4800);
  pinMode(RE, OUTPUT);
  pinMode(DE, OUTPUT);
  if (!display.begin(SSD1306_SWITCHCAPVCC, 0x3C))
  {
    Serial.println(F("SSD1306 allocation failed"));
    for (;;); // Don't proceed, loop forever
  }
  display.display();
  delay(100);
  display.clearDisplay();

  display.clearDisplay();
  display.setTextColor(WHITE);
  display.setTextSize(2);
  display.setCursor(20, 20);
  display.print("PH Meter");
  display.display();
  delay(3000);
}

void loop()
{
  byte val;
  digitalWrite(DE, HIGH);
  digitalWrite(RE, HIGH);
  delay(10);
  if (mod.write(ph, sizeof(ph)) == 8)
  {
    digitalWrite(DE, LOW);
    digitalWrite(RE, LOW);
    for (byte i = 0; i < 11; i++)
    {
      values[i] = mod.read();
      Serial.print(values[i], HEX);
    }
    Serial.println();
  }
  float soil_ph = float(values[4]) / 10;
  Serial.print("Soil Ph: ");
  Serial.println(soil_ph, 1);

  display.clearDisplay();
  display.setTextSize(2);
  display.setCursor(20,0);
  display.println("Ph Value");

  display.setTextSize(3);
  display.setCursor(35,30);
  display.print(soil_ph, 1);

  display.display();

  delay(3000);
}
```

1) Soil Moisture

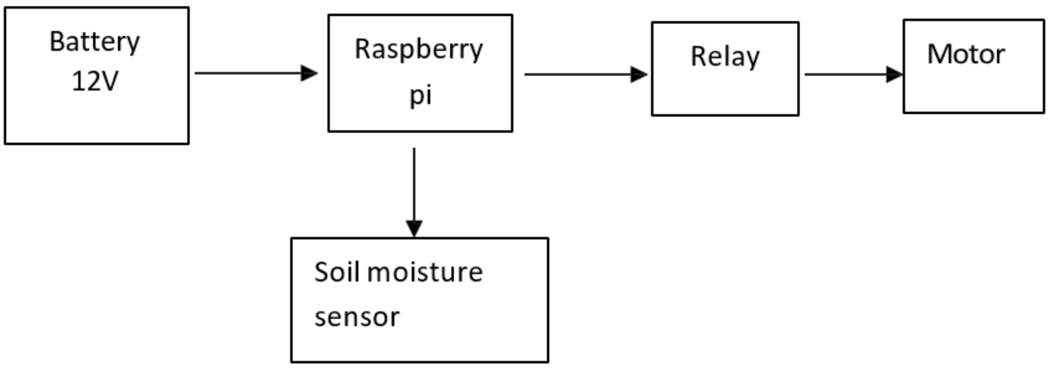
A key component of agriculture, plant growth, and environmental health is soil moisture, which is the quantity of water in the soil. It is an essential component of the water cycle, impacting runoff, groundwater recharge, and plant water availability. Weather patterns, soil composition, and land management techniques are some of the variables that might affect soil moisture level. An instrument called a soil moisture sensor tracks and records the amount of water in clay in a certain region, enabling an estimate about when watering is necessary. Consider the soil moisture sensor as a probe with a wire at the back and a transmitter at the front. Artificial intelligence (AI)-powered sensors are effective tools that have completely changed how data is gathered in the agricultural industry. By giving real-time, precise and actionable insights that increase decision-making, optimize resource management, and increase overall productivity, these technologies provide substantial advantages. Evaluation of Soil Health Sensors gives real-time information on soil moisture, pH, nutrient content, and compaction information. Artificial intelligence (AI) algorithms evaluate this data and recommend soil management practices that enhance the soil's fertility and health. Using these modern AI-driven sensor techniques has been shown to improve data collection accuracy, efficiency, and coverage, which has helped the agriculture sector. The Raspberry PI is the master which sends the signal to Arduino and Arduino Uno is using as

slave which drives a motor driver. Four DC motors are used for movement of
the robot. The Soil moisture sensor is used for check the soil moisture whether it is dry or wet if it is dry then sprinkler the water and also used for spraying fertilizers and water drawn out from sensor and the soil moisture decrease, resistance increase as well as resistance decrease, soil moisture increases and AI voice command is also use to operate the robot movement.

a) **Water Pump Activation**: The water pump is activated when the soil moisture sensor gives a signal indicating dry soil when the moisture level of the soil decreases below the predetermined threshold. The water pump circulates water throughout the system after drawing it from a water source, such as a reservoir or water supply line.

b) **Sprinkler Operation**: Water flows via tubes to sprinkler heads that are placed around the plants. The sprinkler heads irrigate the plants by uniformly distributing water throughout the soil surface.

c) **Monitoring and Modification**: The sensor keeps track of the soil moisture content on a regular basis. The relay shuts off the water pump and shuts off the solenoid valve if the soil moisture level exceeds the predetermined threshold, signifying adequate moisture.




```
const int relayPin = 8;          // Relay control pin
const int sensorPin = A0;        // Soil Moisture Sensor input pin
const int threshold = 20;        // Moisture threshold for irrigation (%)

int sensorValues[10];            // Array to store readings for moving average
int arrayIndex = 0;              // Index for circular buffer
int sumReadings = 0;             // Sum of sensor readings
bool relayState = false;         // Current state of the relay (true = ON)

void setup() {
  Serial.begin(9600);            // Initialize serial communication
  pinMode(relayPin, OUTPUT);     // Set relay pin as OUTPUT
  pinMode(sensorPin, INPUT);     // Set sensor pin as INPUT
  digitalWrite(relayPin, HIGH);  // Turn relay OFF initially (HIGH = OFF for active-low relays)

  // Initialize moving average array
  for (int i = 0; i < 10; i++) {
    sensorValues[i] = analogRead(sensorPin);
    sumReadings += sensorValues[i];
  }

  Serial.println("Soil Moisture Monitoring System Initialized");
}

void loop() {
  // Read sensor value
  int rawValue = analogRead(sensorPin);
  sumReadings -= sensorValues[arrayIndex];  // Subtract oldest value
```

```
  sumReadings += rawValue;                // Add new value
  sensorValues[arrayIndex] = rawValue;    // Update buffer
  arrayIndex = (arrayIndex + 1) % 10;     // Increment and wrap around

  // Calculate average reading
  int averageValue = sumReadings / 10;

  // Map sensor value to percentage (adjust these values for calibration)
  int moisturePercentage = map(averageValue, 550, 10, 0, 100);
  moisturePercentage = constrain(moisturePercentage, 0, 100); // Ensure range is valid

  // Print readings to Serial Monitor
  Serial.print("Raw Value: ");
  Serial.print(rawValue);
  Serial.print(" | Avg Value: ");
  Serial.print(averageValue);
  Serial.print(" | Moisture: ");
  Serial.print(moisturePercentage);
  Serial.println("%");

  // Relay control logic with failsafe
  if (moisturePercentage < threshold) {
    if (!relayState) { // Only activate if not already ON
      digitalWrite(relayPin, LOW); // Turn relay ON
      relayState = true;
      Serial.println("Relay ON - Irrigation Active");
    }
  } else if (moisturePercentage >= threshold) {
    if (relayState) { // Only deactivate if not already OFF
      digitalWrite(relayPin, HIGH); // Turn relay OFF
      relayState = false;
      Serial.println("Relay OFF - Irrigation Stopped");
    }
  }

  // Failsafe: Turn OFF relay if readings are invalid
  if (rawValue < 10 || rawValue > 1023) {
    digitalWrite(relayPin, HIGH); // Turn relay OFF
    relayState = false;
    Serial.println("ERROR: Sensor disconnected or faulty. Relay OFF.");
  }

  delay(1000); // Delay between readings
}
```

Figure 7: Coding

VI. Object detection and leaf disease

Object Detection in Agriculture: Object detection is one of the key aspects of current digital farming, which enables automation for the identification of plant diseases, pest detection, and monitoring of field conditions. It refers to the detection, identification, and localization of objects within images or video frames using advanced machine learning models. Pre-trained object detection models, such as those available on platforms like Kaggle, serve as a starting point to accelerate research and development. These models are trained with large datasets and can be fine-tuned for specific agricultural applications, including plant disease detection.

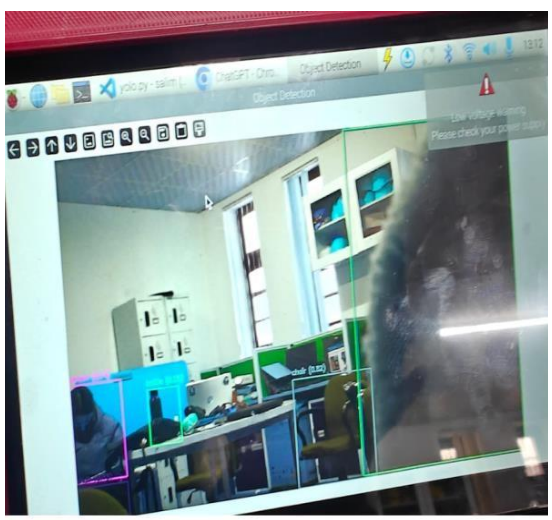


Figure 8: Object detection testing

a) ***Leaf Disease Detection Using Pre-Trained Models***

Plant diseases have a massive impact on crop health and productivity. The traditional method of monitoring crop disease involves manual observation, which is lengthy and error-prone. Automated systems using pre-trained object detection models are more efficient and accurate. Platforms like Kaggle provide datasets along with pre-trained models customized specifically for agricultural applications. These models can be fine-tuned to achieve high accuracy in the identification of various diseases under different environmental conditions, thus making them a cost-effective solution for farmers.

b) **YOLOv8 and Its Application in Agriculture**

YOLOv8 is the latest version in the YOLO family of object detection algorithms. It is well known for speed, accuracy, and efficiency, thus making it highly suitable for real-time applications like agricultural monitoring. It makes use of CNNs in analyzing images and videos for high detection precision with minimal computational requirements, thus being highly applicable to edge devices such as agricultural robots.

Advantages of YOLOv8 in Agriculture

Speed and Efficiency: It processes high- resolution images in real-time, which means action can be taken swiftly in dynamic environments.

Accuracy: Excels at detecting subtle details such as pests or early signs of plant diseases.

Adaptability: Its lightweight architecture ensures smooth integration with autonomous systems such as multifunctional agricultural robots.

Applications of YOLOv8 in Agriculture

Pest Detection: Detects and classifies insects or pests that could threaten crop health.

Plant Health Monitoring: Analyses the plant condition to detect diseases and assess growth stages.

Resource Management: Efficient pesticide application without much waste due to accurate targeting.

Use Cases with Multifunctional Agricultural Robots

While paired with autonomous agricultural robots, YOLOv8 helps perform the following:

- In real-time detection of diseased plants.
- Automatic spraying of chemical through the infestation process
- Mapping of healthy versus unhealthy crop areas for improved resource utilization.

Methodology

Pre-processing and Training Data

Dataset Collection**:** Images of plants are captured from all possible angles, both with and without diseases. The dataset captures different environmental conditions, like light, weather, and the different stages of growth.

Training of the Model: YOLOv8 model fine-tuned with the annotated images. Learning rate, batch size, and epochs for real-time detection performance have been optimized.

Robot Integration

Sensor Systems: The Robot is fitted with high- definition cameras and sensors.

Real-Time Analysis: The YOLOv8 model processes images coming from the sensors, detecting the most relevant objects such as pests or diseased crops.

Automated Action: Depending on the outcome of the detection, the robot will spray chemicals or flag the respective crops for human intervention.

```python
import time
import cv2
import numpy as np
import RPi.GPIO as GPIO
from picamera2 import Picamera2
from ultralytics import YOLO
import threading

# Constants for better readability and easy maintenance
DETECTION_THRESHOLD = 0.1  # Detection threshold for YOLOv8
IMAGE_SIZE = (320, 320)  # Reduced resolution for faster processing
SKIP_FRAMES = 2  # Skip every 2nd frame to improve frame rate
SMOOTH_MOVEMENT_INTERVAL = 200  # Move camera every 200 frames

# Load pre-trained YOLOv8 model for object detection
model = YOLO('yolov8.pt')  # Replace with your actual YOLOv8 model path

# GPIO setup for controlling pan motor (assuming PWM for pan)
GPIO.setmode(GPIO.BCM)
GPIO.setup(17, GPIO.OUT)  # GPIO pin for pan motor

pan_pwm = GPIO.PWM(17, 50)  # 50Hz frequency for PWM
pan_pwm.start(0)  # Start PWM with 0 duty cycle
```

Figure 9: code for object detection

```python
# Leaf Disease Class Names and Descriptions
class_names = ['healthy', 'spotted', 'dry', 'blight', 'mildew', 'rust', 'yellowing', 'wilting', 'pest_damage']

class_descriptions = {
    'healthy': ('No care needed', 'No disease present'),
    'spotted': ('Use fungicide, improve air circulation', 'Caused by fungal or bacterial infections'),
    'dry': ('Water regularly, increase humidity', 'Caused by dehydration or environmental stress'),
    'blight': ('Remove affected leaves, use fungicide', 'Caused by fungal or bacterial pathogens'),
    'mildew': ('Remove infected leaves, apply antifungal treatments', 'Caused by fungal spores'),
    'rust': ('Apply fungicides, remove infected leaves', 'Caused by fungal pathogens'),
    'yellowing': ('Ensure proper nutrients, balance pH', 'Caused by nutrient deficiency or pests'),
    'wilting': ('Water properly, check for root damage', 'Caused by water stress or root problems'),
    'pest_damage': ('Use insecticides, remove pests manually', 'Caused by insects or pests feeding on leaves')
}

# Initialize Servo for leaf disease detection
servo = Servo(17)
```

Figure 10: Code for leaf diseases detection

Challenges and Future Directions

Environmental Variability: The accuracy of detection will vary depending on lighting conditions, weather, and plant growth stages. Diverse training data must be collected.

Data Annotation: Large datasets need to be manually annotated and are expertise-intensive in plant diseases and pests.

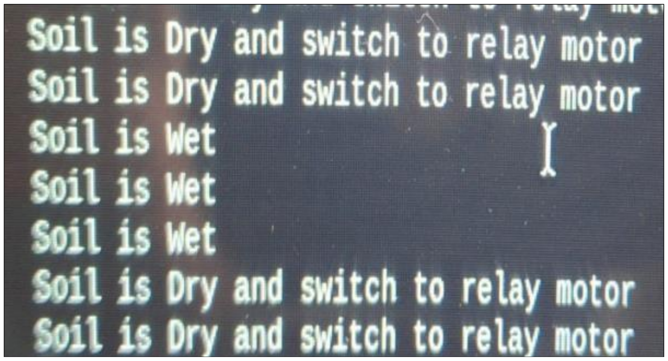
Deployment Challenges: Testing and optimization of the robot on different agricultural terrains and crop types is needed for wide deployment.

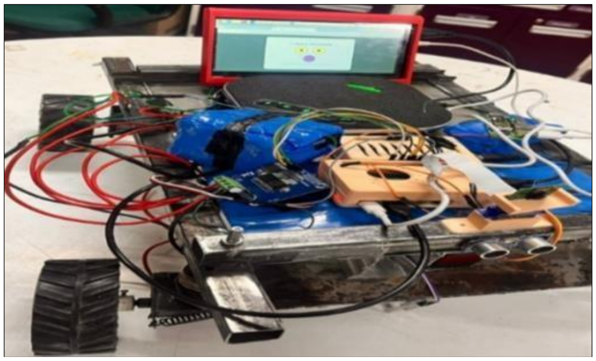
Parameter	AI Based Smart Agriculture Robot	Paper 1: Agricultural Robot with IoT and Deep Learning for Weed Control	Paper 2: Multipurpose Agricultural Robot Powered by Solar Energy	Paper 3: IoT-Based Smart Agriculture Robot for Multiple Operations
Power Source	Solar and SMPS.	Solar	Solar	Solar
Chassis Design	Multipurpose agriculture applications.	Agriculture tasks.	Multipurpose agricultural applications.	Range of agricultural tasks.
Battery Type	Lithium-ion	Lithium Iron Phosphate	Lithium-ion	Lithium-ion
Solar Panel	Môn crystalline	Polycrystalline	Polycrystalline	Polycrystalline
Charging Time	2-2.5hrs	2-4hrs	4-5hrs	4-8hrs
Technology Used	IoT, Deep Learning, AI, Robotics, Solar energy, Machine Learning, BMS, MPPT.	IoT, Deep Learning, Machine vision, Weed control.	Solar energy.	IoT, Solar energy, Robotics, Precision agriculture.
Purpose of Robot	To check soil fertility, health and analysis, Water sprinkler, Monitoring, Voice command, real-time object detection, plant disease detection.	Weed control.	Planting, Harvesting, Spraying.	Weeding, Spraying, Monitoring.
Sensors Used	Cameras, Soil moisture sensor, pH sensor, Ultrasonic sensor, Humidity and Temperature sensor.	Camera for weed detection.	Cameras, GPS, other sensors for automation.	Cameras, GPS, Soil moisture sensor and temperature sensor.
Communication Protocols	BLE, Wi-Fi, USB, I2S, I2C, HTTP, LoRa, MQTT, SPI, PI- CAM.	BLE, LoRa, Wi-Fi, MQTT, HTTP.	ESP32-CAM, Node MCU.	Wi-Fi, Bluetooth, LoRa, MQTT, HTTP.
Display	7-inch LCD	No	No	No
Multiple interface	Voice command, Bluetooth, Remote, Keyboard. GUI	Bluetooth	Remote	Remote

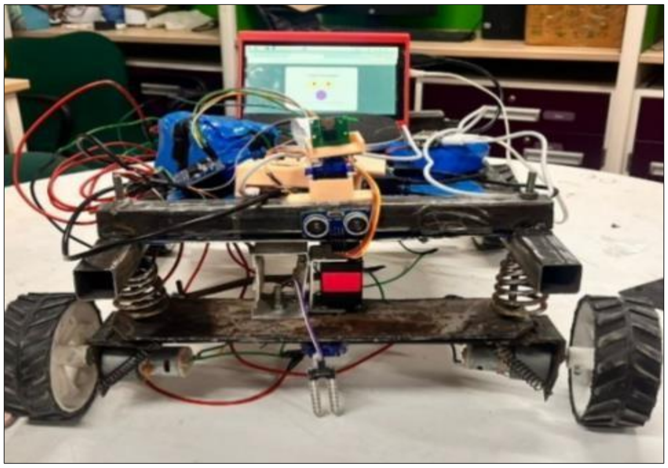
Table 6: Comparison Table

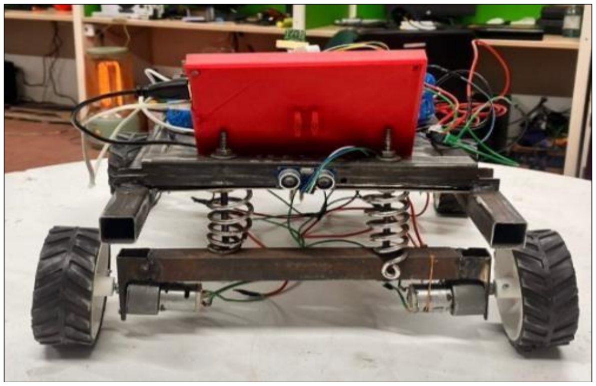
6. RESULT

SOIL MOISTURE OUTPUT
Optimal range:
<500: The soil is too wet
500-750: Target range for soil moisture
>750: Soil is dry enough to water Testing: Soil sample









Sample: soil from a garden

Soil is Dry: The soil is dry with moisture level below the optimal range.
Soil is wet: The soil is wet with moisture levels above the optimal range

B. pH OUTPUT
Sample: Garden soil
Sensor Reading: pH = 6.8

Interpretation
The soil is slightly acidic. Which is within the optimal range This pH level indicates the soil is suitable for growing common vegetables, flowers, and fruits

Optimal range
Acidic soils: pH<7 Neutral soils: pH=7 Alkaline soils: pH>7

7. CONCLUSION

The agricultural robot developed in this paper addresses the challenges that farmers face in regions like Ladakh, where environmental conditions are harsh and farming is difficult. Combining modern technologies such as IoT, AI, and robotics, the robot offers efficient solutions for essential tasks like soil analysis, crop monitoring, water and pesticide spraying, and voice-controlled operations. This system also reduces labor and costs while providing better productivity and precision in agriculture. The installation of renewable sources of energy like solar panels, and an advanced management system for a battery, means the robot would be sustainable as well as dependable in any climate. The implementation of a Ladakhi local voice assistant to the robot ensures that it would be more user-friendly and helpful for farmers. Overall, the innovation promotes smart and sustainable farming practices, hence allowing farmers to respond to modern agricultural challenges in an environmentally friendly way and better living conditions.

FUTURE WORK

Advanced AI and Internet of Things capabilities could be added to agricultural robots in the future to improve disease diagnosis, weather forecasting, and crop monitoring. To address Ladakh's environmental requirements, it can be further tailored to use solar energy and adjust to the native crop and soil types. More languages can be supported by the voice assistant, which can also offer customized guidance on market prices, government programs, and agricultural methods. To increase efficiency, autonomous navigation and tasks like planting and harvesting can be incorporated. Furthermore, the robot's scalable design and environmentally acceptable components will enable it to be used in other difficult agricultural areas across the world.

REFERENCES

1. Meti AG, Biradar KS. IoT and Solar Energy-Based Multipurpose Agricultural Robot for Smart Farming. In: 2022 IEEE International Conference on Data Science and Information System (ICDSIS); 2022.
2. O' Kennedy S. Soil pH and its impact on nutrient availability and crop growth. Int J Geogr Environ. 2022;4(2):236-8.
3. Jenath M, Sinnur R, Bhogavelli VK, Jagadish B. Terrestrial Moisture Sensor using IoT and Neutralizing pH Value of the Soil. In: 10th International Conference on Communication and Signal Processing (ICCSP); 2024.
4. Nitnaware PA, Khandait AP. Smart Soil Moisture Sensing and Automatic Water Irrigation Robot. Int Res J Eng Technol (IRJET). 2022; e-ISSN:2395-0056.
5. Umesha BC, Prashanth. Plant irrigation Water Sprinkler Robot. Int Res J Mod Eng Technol Sci (IRJMETS). 2024; e-ISSN:2582-5208.
6. Abhyankar VV, Gavade SA, Bhole KS. System Development for Simultaneous Measurement and Control of pH and Moisture of Soil. In: International Conference on Nascent Technologies in Engineering (ICNTE); 2019.
7. Prakash KJ, Kalyan KP, Basha SM. Autonomous Robot for Field Health Indication and Crop Monitoring System using Artificial Intelligence. In: 2nd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE); 2022.