A

PROJECT REPORT

On

Landmine Detection Robotic Vehicle Using ARM Cortex (STM32)

Submitted in partial fulfilment of the academic requirements
For the award of the degree of

BACHELOR OF TECHNOLOGY
In
ELECTRONICS AND COMMUNICATION ENGINEERING
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AUTONOMOUS INSTITUTION
Accredited by NAAC with ‘A’ grade, NBA Accredited B.Tech. Programs
Divyanagar, Medchal – Malkajgiri (Dt), Ghatkesar(M), Narapally – 500088

2024 – 2025

NALLA MALLA REDDY ENGINEERING COLLEGE

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Divyanagar, Ghatkesar, Medchal Dist.

CERTIFICATE

This is to certify that the project entitled "**Landmine Detection Robotic Vehicle Using ARM Cortex (STM32)**" is being submitted by **A.vivek (22B65A0408), B.Akshay (22B65A0418)** and **CH.Adarsh (22B65A0423)** in partial fulfilment of the academic requirements for the award of degree of Bachelor of Technology in **ELECTRONICS AND COMMUNICATION ENGINEERING** in NALLA MALLA REDDY ENGINEERING COLLEGE, Autonomous Institution, JNTU - HYDERABAD during the academic year 2024-2025.

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CANDIDATE’S DECLARATION

We hereby declare that the project report entitled “**Landmine Detection Robotic Vehicle Using ARM Cortex (STM32)**” is the bona-fide work done and submitted by me under the guidance of **Dr.R. Jawaharlal**, in partial fulfilment of the requirements for the degree of **Bachelor of Technology in Electronics and Communication Engineering** to the Department of Electronics & Communication Engineering, **Nalla Malla Reddy Engineering College**, Divya Nagar, Medchal-Malkajgiri Dist.

Further we declare that the report has not been submitted by anyone to any other institute or university for the award of any other degree.

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ABSTRACT

The "Landmine Detection Robotic Vehicle with GPS Positioning Using STM32" project is designed to enhance safety and efficiency in landmine detection through advanced robotics. The system utilizes an STM32F103C8T6 microcontroller to orchestrate various components aimed at detecting and locating landmines. A metal detector sensor is employed to identify metallic objects, with the system programmed to send alerts via GSM if a mine is detected, including the precise GPS coordinates of the location. The robotic vehicle is powered by DC motors, which are controlled through a motor driver module and Bluetooth interface, allowing for directional movement (forward, backward, right, left). The setup includes buzzers for sound alerts to indicate detection or operational status, and a robot chassis with wheels for mobility. The integration of these components ensures a robust and efficient landmine detection system, combining real-time detection with precise location tracking to improve safety and operational effectiveness in hazardous environment

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CHAPTER-1

INTRODUCTION

1.1 Introduction

1.1.1 Overview of Landmine Detection Systems

Landmines continue to be a major global concern, particularly in post-war zones, where unexploded mines pose severe risks to civilians and military personnel. These landmines remain active for decades, causing **thousands of deaths and injuries every year**. Conventional landmine detection techniques, such as **manual detection using metal detectors and trained sniffer dogs**, are not only inefficient but also expose human and animal lives to extreme danger. To address these challenges, **robotic landmine detection systems** have emerged as a viable alternative. By integrating **autonomous movement, sensor technology, GPS tracking, and wireless communication**, these systems enhance **detection accuracy, minimize human risk, and speed up demining operations**. The development of an **STM32-based robotic vehicle** for landmine detection is a step toward a safer and more reliable solution.

1.1.2 Importance of Automated Landmine Detection

Landmine detection is a **time-sensitive and high-risk** operation. The deployment of **automated robotic systems** is essential for:

- **Improving safety:** Reducing human and animal exposure to hazardous areas.
- **Enhancing efficiency:** Robots can **scan large areas faster** compared to manual methods.
- **Increasing detection accuracy:** Reducing **false positives** using smart sensor integration.
- **Remote operation capability:** Allowing operators to **monitor and control the robot wirelessly** from a safe distance.
- **Cost-effectiveness:** Providing an **affordable and scalable** solution compared to expensive AI-based or radar-based detection methods.

1.1.3 Role of Robotics in Hazardous Environments

Robotics plays a **critical role** in modern demining operations by:

- **Enabling autonomous navigation** in high-risk areas where human access is unsafe.
- **Utilizing advanced sensors** such as metal detectors and ground-penetrating radar (GPR) to detect landmines.
- **Integrating GPS tracking** to mark detected landmine locations on a digital map.
- **Providing real-time monitoring** through a camera module for operator-assisted confirmation.
- **Improving operational flexibility**, allowing both manual remote control and AI-assisted decision-making.

Robots significantly **reduce the time, cost, and danger** associated with traditional landmine clearance, making them an indispensable tool in humanitarian and military operations.

1.1.4 Objectives of the Project

The primary objective of this project is to develop an **autonomous robotic vehicle** using an **STM32 microcontroller** to detect landmines safely and efficiently. The key goals include:

- **Designing and implementing an STM32-based robotic platform** for landmine detection.
- **Integrating a metal detector sensor** to identify buried metallic landmines.
- **Incorporating GPS tracking** to log the exact coordinates of detected landmines.
- **Enabling wireless communication** using a Bluetooth module (HC-05) for real-time data transmission.
- **Adding an ESP32-CAM module** to provide a **live video feed** for remote monitoring.
- **Using an L298N motor driver** to control the movement of the robotic vehicle across different terrains.
- **Enhancing battery efficiency** for extended field operations.
- **Minimizing false positives** through sensor calibration and software optimization.

- **Providing an affordable, scalable, and reliable alternative** to existing landmine detection methods.

1.1.5 Scope of the Project

This project serves as a **foundation for future advancements in robotic landmine detection**, with potential improvements including:

- **Integration of AI algorithms** for **more precise landmine detection**.
- **Deployment of ground-penetrating radar (GPR)** for non-metallic mine detection.
- **Solar-powered operation** to enhance battery life and field endurance.
- **Long-range wireless communication** using LoRa or 5G connections.

1.2 Literature Survey:

As stated in, the objective of this article is to establish a design and create intelligence through the use of a Microsoft Kinetic controller in order to control the bomb disposal robot. The disadvantage is the robotic arms can only lift lightweight objects. Here the wheels can only manoeuvre on flat surfaces. This paper describes the design and execution of a simulated mobile robot that detects hidden landmines on the battlefield in order to minimize human interaction . The robot that detects buried landmines is the main focus of this research. As a result of the sensor being overloaded, the robot's weight is its primary drawback. The goal of this project is to create a multi- sensor robotic system for the semi-autonomous detection of landmines. This paper details the work made on tripwire detection inside the Landmine Detection . Sensors include ground penetrating radar (GPR) and holographic subsurface radar (HSR) for the detection of buried mines and a tripwire sensor for the detection of side-attack and directional landmines. The GPR and HSR are currently integrated with the robot via ROS, and the tripwire detector will be implemented in the same manner once it has been further developed. More work is required to develop the theory as to why this works so effectively. Additional improvements on algorithms are not made. Picture processing and picture improvements are also the most crucial elements for applications used underwater . This paper experiences and evaluates the application of the Transfer Learning approach for underwater item recognition. Underwater fish species identification is achieved with the application of the Yolo deep learning technology. A camera equipped ROV is used to broadcast footage underwater, and the primary computer has processed and examined the data. Our test findings verified a 4% map improvement using transfer learning. One modified bug controller has been proposed for mobile robot path navigation in simulation and real-time environments . One land mine detection robot has been implemented for motion Planning . One SAWOA algorithm is proposed for GPS based path tracking of a non-holonomic robot in different simulation and real- time environments . An automated decision setup to detect landmine in hazardous environments with the help of metal detector signals .

A novel Borahsid algorithm is proposed for experimental analysis of a quad wheel autonomous robot path planning in different environments with GPS and Zigbee sensors . Different mine detection and sensing technologies can be seen in . A new obstacle-avoiding algorithm is proposed for mobile robot path navigation with multiple experimental analyses . Deep neural networks are also used for underwater mine detection . A modified particle swarm optimization method is used for autonomous navigation with V-REP experimental model analyses . Fuzzy Logic based algorithm is also one of the research concerns in underwater mine detection . A novel DFMB algorithm has been introduced in MATLAB simulation environment for autonomous driving .

CHAPTER-2

PROJECT OVERVIEW AND SYSTEM ARCHITECTURE

2.1 Overview of the Project

Landmine detection requires high accuracy, efficiency, and safety to prevent casualties in war-affected regions. This project presents an autonomous landmine detection robotic vehicle integrating metal detection, GPS tracking, wireless communication, and real-time video surveillance.

Key Features of the System

- STM32 microcontroller-based control system for processing sensor data and controlling the robot.
- Metal detector module for identifying buried metallic landmines.
- GPS module (NEO-6M) for location tracking and precise minefield mapping.
- Bluetooth (HC-05) communication module for remote monitoring and control.
- ESP32-CAM module for live video feed and real-time object verification.
- L298N motor driver for smooth movement and terrain adaptability.
- Buzzer alert system to notify the operator upon landmine detection.
- Rechargeable Li-Po battery for extended field operation.

2.2 Block Diagram of the System

A block diagram of the robotic system provides an overview of the functional components and their interconnections.

Main Blocks in the System

- Microcontroller (STM32F103C8T6): Central processing unit managing all operations.

- Metal Detector Sensor: Scans for underground metallic objects.

- GPS Module (NEO-6M): Captures the robot’s location and transmits data.
- Bluetooth Module (HC-05): Enables wireless data transmission to the operator.
- ESP32-CAM Module: Streams live video for remote monitoring.
- Motor Driver (L298N): Controls the movement of the robotic vehicle.
- Power Supply (Li-Po Battery): Provides power to the system.
- Buzzer & LED Alert System: Signals landmine detection to nearby personnel.

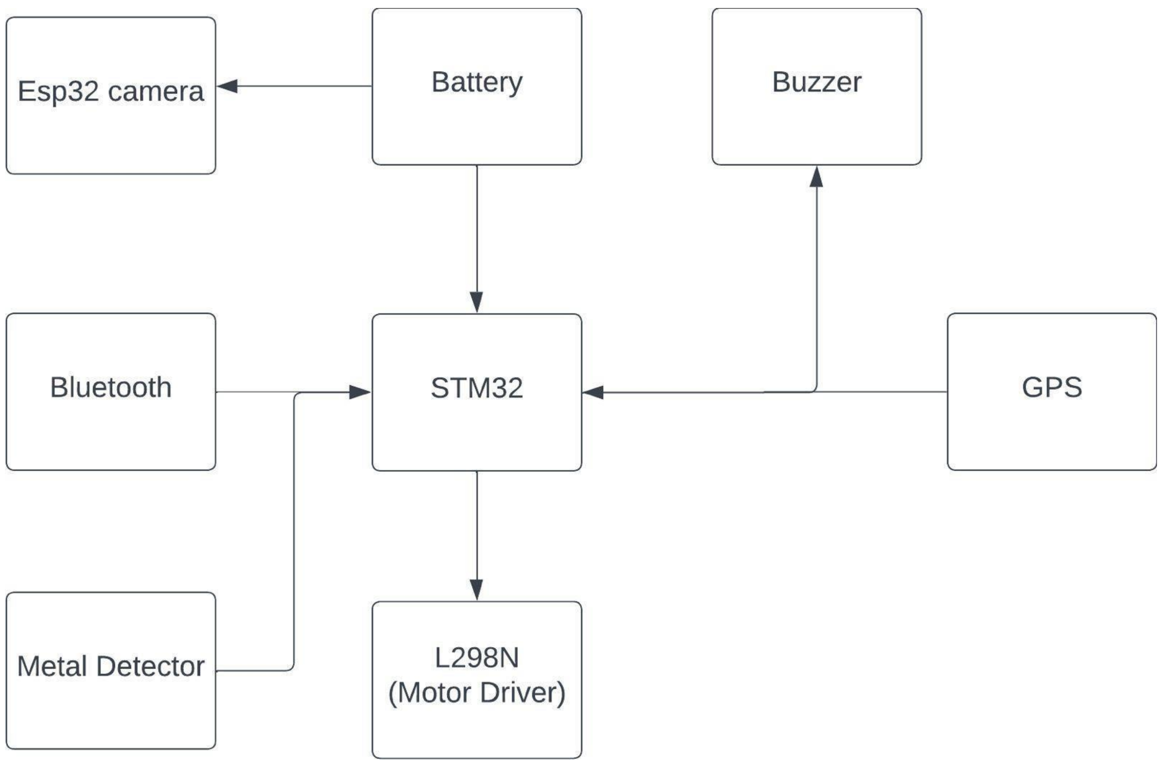


Figure 1: Block Diagram of the System

2.3 Functional Modules in the Robotic System

2.3.1 Metal Detection Module

- Utilizes an electromagnetic induction-based metal detector to detect landmines.
- Generates an alert signal when metal is detected.
- Sends detection data to the STM32 microcontroller for processing.

2.3.2 GPS Tracking Module

- Uses the NEO-6M GPS module to determine the exact location of detected landmines.
- Sends precise latitude and longitude coordinates to the microcontroller for processing.
- Assists in creating a real-time minefield map, improving the safety and efficiency of demining operations.
- Provides continuous location tracking as the robot moves across the field.
- Allows for accurate marking and logging of hazardous zones for future reference.
- Integrates seamlessly with mapping software to visualize detected landmine positions on digital maps.

2.3.3 Wireless Communication Module

- HC-05 Bluetooth Module enables wireless communication between the robot and the operator's mobile device.
- Allows remote control of the robot's movement and monitoring through a custom mobile app.
- ESP32-CAM Module streams real-time video, providing visual feedback for identifying potential landmines.
- Enhances situational awareness and decision-making by combining video feed with GPS and sensor data.

2.3.4 Motor Control Module

- Supports control of two DC motors simultaneously with individual speed and direction.
- Enables precise turning and maneuvering through differential drive logic.
- Integrates with microcontrollers (e.g., Arduino, ESP32) easily through PWM and logic pins.
- Includes onboard heat sink for effective heat dissipation during prolonged operation.
- Compatible with both 5V and 12V motors, offering flexibility in motor selection.
- Protects connected motors with built-in diodes that handle voltage backflow.
- Can be powered through external battery packs, ensuring consistent performance.
- Allows for manual override or remote control through appropriate wiring configurations.
- Contributes to obstacle avoidance and pathfinding when integrated with sensor feedback.
- Plays a vital role in enabling autonomous or semi-autonomous robotic behaviors.

2.3.5 Power Supply System

- Uses a 12V Li-Po rechargeable battery to power the system.
- Ensures long-lasting operation in outdoor conditions.
- Includes voltage regulation circuits to supply proper voltage to different modules.

2.4 System Architecture

2.4.1 Data Flow in the System

1. Metal Detector Sensor scans for landmines. If metal is detected, a signal is sent to STM32.
2. STM32 processes the detection signal, triggers the buzzer, and records GPS location.

3. GPS Module fetches real-time location data and sends coordinates to STM32.
4. Bluetooth (HC-05) transmits detection alerts and mine location to the operator's mobile device.
5. ESP32-CAM captures live video feed for remote visual confirmation of the detected object.
6. L298N motor driver controls movement, navigating the robot over different terrains.
7. Power Supply manages system energy consumption, ensuring stable operation in the field.

2.4.2 Control Logic

- **Autonomous Mode:** Robot scans for landmines and marks locations automatically.
- **Manual Mode:** Operator controls robot movement via a Bluetooth-connected mobile app.

2.5 Advantages of the System

- Automated landmine detection reduces human risk.
- Real-time GPS tracking ensures precise mapping of detected landmines.
- Wireless communication allows remote monitoring and control.
- Live video feed improves detection accuracy and decision-making.
- Cost-effective and scalable for large-scale demining operations.

CHAPTER-3
METHODOLOGY

1.1 Existing Methodology

The existing system consists of an ESP32-CAM module that captures real-time images or video of the environment. These images are transmitted wirelessly via a Wi-Fi module to a remote server or cloud platform. In the cloud, an object detection algorithm processes the received images to identify specific objects of interest, such as tools or obstacles. Based on the detection results, appropriate control commands are generated and sent to a robotic arm. The robotic arm then performs the required physical actions—such as picking up, moving, or sorting objects—based on the instructions. This setup enables automated object recognition and manipulation using low-power embedded hardware and cloud-based intelligence.

1. **ESP32-CAM**
    - Captures live video or images of the environment.
    - Transmits the captured media wirelessly for further processing.
2. **Wi-Fi Module**
    - Provides wireless communication capability.
    - Sends image data to a remote server or cloud service.
3. **Object Detection in Cloud**
    - Received images are processed using an object detection algorithm in the cloud.
    - Identifies objects of interest (e.g., tools, obstacles).
4. **Robotic Arm Control**
    - Based on the object detection results, appropriate control commands are generated.
    - Commands are sent to the robotic arm for picking or interacting with the object.
5. **Actuator / Robotic Arm**
    - Executes physical actions such as picking, placing, or sorting objects as instructed.

ROBOTIC KINEMATICS

- Forward kinematics of differential drive robot consists of calculating the end point of robot, while knowing the start point and velocities of both wheels.
- Following equations are used to calculate the final point of robot.

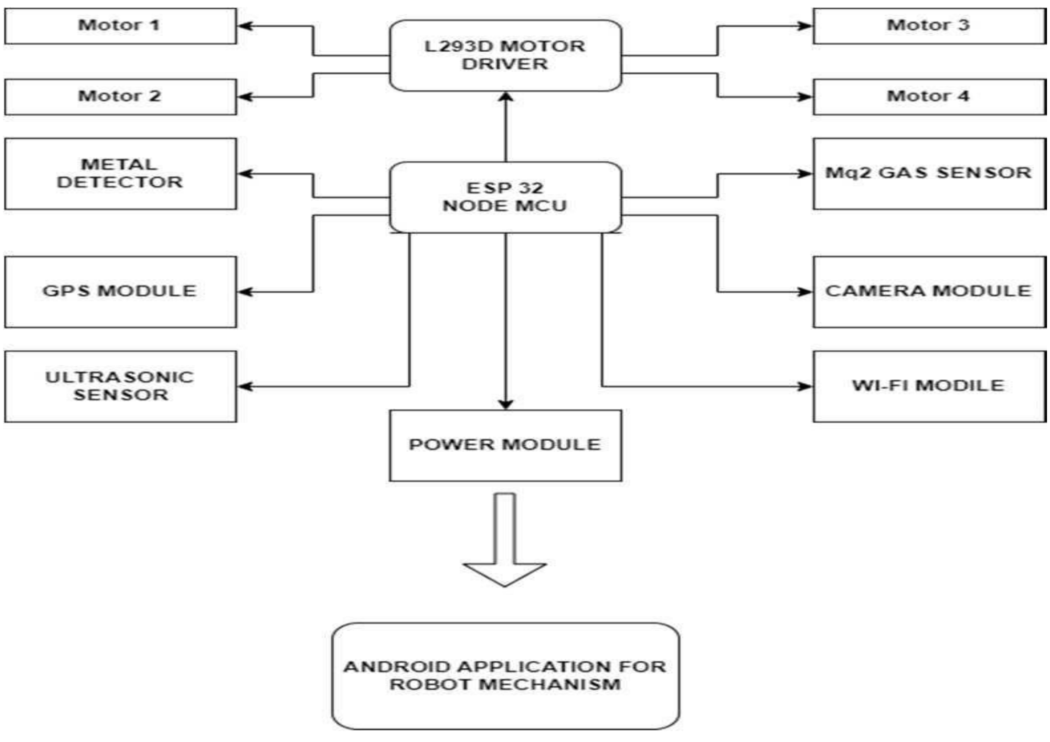
$$x^t = \frac{v^l + v^r}{2} \sin\theta \qquad (1)$$

$$y^t = \frac{v^l + v^r}{2} \cos\theta \qquad (2)$$

$$\theta^t = \frac{v^l - v^r}{D^w} \qquad (3)$$

Where x^t, y^t, θ^t are the linear and angular velocities of robot. v^l and v^r are the velocities of the wheel of differential drive. D^w is the distance between the two wheels. θ is the orientation of robot.

Flow Chart:



3.2 Proposed Methodology:

The proposed method involves an advanced robotic vehicle equipped with a metal detector sensor, STM32 microcontroller, GPS, GSM module, and Bluetooth for autonomous landmine detection and location tracking. The vehicle uses the metal detector to identify mines, with the STM32 processing the sensor data and controlling the vehicle's movement via DC motors and a motor driver module. Upon detecting a mine, the system sends an immediate alert through the GSM module, including the precise GPS coordinates of the detected mine, allowing for prompt and accurate communication. The Bluetooth module enables remote control of the robot's movement, enhancing its maneuverability in complex terrains. The integration of a buzzer provides immediate audio alerts when a mine is detected, ensuring rapid response to potential threats. This method enhances safety, efficiency, and accuracy in landmine detection, reducing manual labor and minimizing risks.

3.3 Case Studies

Several case studies have demonstrated the effectiveness of robotic vehicles equipped with arms for landmine detection and removal. One notable example is the use of autonomous ground vehicles integrated with robotic arms and metal detectors to locate and safely extract landmines in post-conflict zones. In these systems, the robotic arm is programmed to approach the detected object with precision, excavate the soil, and remove or disable the mine without endangering human life. Another study utilized a robotic platform with vision-based detection and AI-driven decision-making to identify suspected landmines and deploy the arm for controlled handling. Additionally, some research projects have implemented teleoperation systems, where human operators remotely control the robotic arm for delicate disarming tasks, supported by real-time video and sensor feedback. These case studies highlight the crucial role of robotic arms in enhancing safety, accuracy, and efficiency in landmine clearance operations.

CHAPTER-4
Hardware Description

4.1 Overview

The hardware implementation of the landmine detection robotic vehicle involves the integration of various electronic components, sensors, and actuators to enable real-time landmine detection, GPS tracking, wireless communication, and remote monitoring. The system is built around an STM32 microcontroller, which acts as the central processing unit, interfacing with the metal detector, GPS module, Bluetooth module, ESP32-CAM, motor driver, and power supply. The design ensures efficient energy consumption, robust sensor integration, and reliable mobility for rough terrains.

4.2 Power Supply System

The power supply system is a critical component of the landmine detection robotic vehicle, ensuring that all electronic modules and motors receive stable voltage and current for reliable operation. The system is designed to provide efficient energy distribution, voltage regulation, and protection against power fluctuations to maximize battery life and overall system performance.

Battery Selection

The robotic vehicle is powered by a 12V Li-Po (Lithium Polymer) rechargeable battery, chosen for its high energy density, lightweight properties, and stable voltage output. Li-Po batteries provide consistent power delivery to motors and electronic components, ensuring uninterrupted operation in the field. The battery capacity (measured in mAh) determines the runtime of the system, with a 2000mAh–5000mAh battery typically used for extended operation.

Voltage Regulation

Different components in the system require different operating voltages. To prevent overvoltage or undervoltage issues, **voltage regulators** are used to step down the battery voltage to required levels. The voltage regulation system consists of:

- **LM2596 DC-DC Buck Converter:** Steps down **12V to 5V** for components such as the metal detector, Bluetooth module, and ESP32-CAM.

- **LM1117 Voltage Regulator:** Converts **5V to 3.3V** for low-power components such as the STM32 microcontroller and GPS module.
- **L298N Motor Driver Voltage Input:** Motors receive **direct 12V power** from the battery for optimal torque and speed.

Power Distribution

To ensure proper power delivery to all modules, the power supply system is structured as follows:

- **STM32 Microcontroller:** Receives **3.3V** from the LM1117 regulator.
- **Metal Detector Module:** Operates on **5V**, powered by the buck converter.
- **GPS Module (NEO-6M):** Requires **3.3V**, provided through the STM32 power rail.
- **HC-05 Bluetooth Module:** Operates on **3.3V for logic signals**, but **5V for power**, regulated by the buck converter.
- **ESP32-CAM Module:** Requires **5V** for proper Wi-Fi operation and video streaming.
- **L298N Motor Driver & DC Motors:** Receives **12V** directly from the battery for full power delivery to the motors.

Current Requirements and Load Distribution

The **total power consumption** of the robotic system is calculated based on the **current draw of each component**. A **high-discharge Li-Po battery** is used to meet peak current demands, especially when motors and sensors operate simultaneously.

- **STM32 Microcontroller:** ~50mA
- **Metal Detector:** ~150m

GPS Module: ~60mA

- **Bluetooth Module (HC-05):** ~30mA in idle, ~200mA during transmission
- **ESP32-CAM:** ~180mA–300mA during video streaming
- L298N Motor Driver + Motors: 1A–2A per motor, depending on the load

The system is designed to **distribute current efficiently** without overloading any single voltage regulator.

Battery Charging and Protection

To extend battery life and prevent damage, a **battery management system (BMS)** is integrated into the power supply. Key protection features include:

- **Overcharge Protection:** Prevents excessive voltage during charging.
- **Over-Discharge Protection:** Cuts off power when battery voltage drops below a safe limit (typically **10V for a 12V Li-Po**).
- **Short Circuit Protection:** Prevents excessive current draw in case of a wiring fault.
- **Thermal Protection:** Monitors battery temperature to avoid overheating.

A **smart battery charger** is used to recharge the Li-Po battery, supporting **balanced charging** to maintain battery health and efficiency.
communication error. By adding an audio alert system, the robot provides an additional layer of feedback, enhancing the user experience and operational safety.

4.3 STM32 Microcontroller Setup

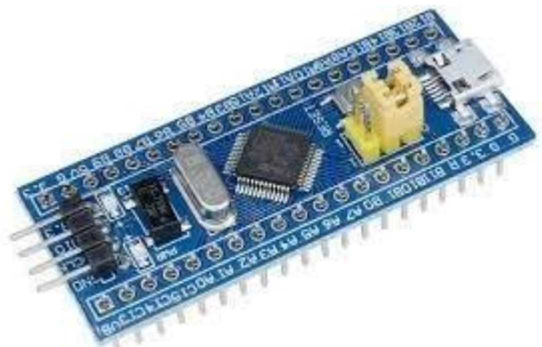


Figure 2: STM32 Microcontroller

The **STM32F103C8T6** microcontroller is the central processing unit of the landmine detection robotic vehicle, responsible for handling sensor inputs, processing data, controlling motors, and managing wireless communication. It is based on the **ARM Cortex-M3** architecture, offering **low power consumption, real-time processing capabilities, and multiple communication interfaces** for seamless integration with external modules.

Features of STM32F103C8T6

- **Core:** ARM Cortex-M3, 32-bit, 72 MHz clock spee
- **Flash Memory:** 64 KB (for program storage)
- **SRAM:** 20 KB (for runtime data storage)
- **GPIO Pins:** 37 configurable I/O pins
- **Communication Interfaces:** UART, I2C, SPI for sensor and module interfacing
- **PWM Support:** Controls motor speed and direction
- **Low Power Modes:** Reduces energy consumption for battery-powered operation

Microcontroller Role in the System

The STM32 microcontroller is responsible for managing all essential functions of the robotic vehicle, including:

- Reading sensor inputs from the metal detector to detect landmines
- Processing GPS data to log real-time location tracking
- Controlling the L298N motor driver to navigate the robot
- Communicating with the HC-05 Bluetooth module for wireless monitoring
- Interfacing with the ESP32-CAM module for live video streaming
- Activating the buzzer and LED alerts when a landmine is detected

Pin Configuration and Interfacing

The STM32 microcontroller interacts with multiple components via dedicated GPIO pins. The main connections include:

- **Metal Detector:** Connected to a digital input pin, detecting HIGH/LOW signals when metal is found
- **GPS Module (NEO-6M):** Uses UART for receiving real-time coordinates
- **HC-05 Bluetooth Module:** Uses UART for sending detection alerts and GPS data
- **ESP32-CAM:** Uses UART for triggering image capture and data transmission
- **L298N Motor Driver:** Uses PWM pins to control motor speed and direction

- **Buzzer and LED Alert System:** Controlled via GPIO pins to signal landmine detection

Microcontroller Programming and Setup

The STM32 is programmed using **Arduino IDE and STM32CubeIDE**, allowing for efficient firmware development. The steps for setting up the STM32 include:

1. **Installing STM32 Board Support in Arduino IDE** for programming the microcontroller.
2. **Writing initialization code** to configure GPIOs, UART, PWM, and I2C interfaces.
3. **Developing the main program loop** to continuously scan for sensor input and process detection data.
4. **Implementing serial communication protocols** for GPS, Bluetooth, and ESP32-CAM.
5. **Testing and debugging using a serial monitor** to verify sensor responses and motor control.

Real-Time Processing and Decision Making

The STM32 microcontroller continuously monitors sensor inputs and makes real-time decisions based on detection data. When a landmine is detected, it immediately:

- Logs GPS coordinates and sends them via Bluetooth to the operator
- Triggers the buzzer and LED alert system
- Captures an image or video feed from the ESP32-CAM for verification
- Adjusts motor movement if required to avoid obstacles

Conclusion

The STM32F103C8T6 microcontroller plays a crucial role in ensuring the **real-time operation, sensor integration, and communication management** of the landmine detection robotic vehicle. Its efficient processing capabilities enable **fast response times,**

seamless wireless data transmission, and precise motor control, making it an ideal choice for this embedded system. Future upgrades could include **AI-based data processing, cloud integration, and enhanced power optimization** for extended field operation.

4.4 Metal Detector Integration

Figure 3: Metal Detecor

The **metal detector module** is a critical component of the landmine detection robotic vehicle, responsible for identifying buried metallic objects that could potentially be landmines. The metal detector operates on the principle of **electromagnetic induction**, where a fluctuating magnetic field interacts with nearby metallic objects, producing a detectable signal. The STM32 microcontroller processes this signal to trigger alerts and log GPS coordinates.

Working Principle of the Metal Detector

The metal detector generates an **alternating electromagnetic field** using a coil. When a metallic object disturbs this field, **eddy currents** are induced in the object, producing a secondary magnetic field. This interaction causes a change in the coil's impedance, which is detected by the sensor and converted into a digital output. The STM32 microcontroller reads this signal and determines if a metallic object is present.

Metal Detector Interfacing with STM32

The metal detector module is connected to the STM32 microcontroller via a **digital input pin**. The sensor provides a HIGH (1) signal when no metal is detected and a LOW (0) signal when a metallic object is found. The STM32 continuously monitors this input and, upon detecting a LOW signal, triggers an alert system and logs the GPS location.

Detection Process and Alert Mechanism

1. The STM32 continuously reads the digital signal from the metal detector.
2. If the signal changes from HIGH to LOW, the system identifies the presence of a metallic object.
3. The microcontroller triggers the **buzzer and LED alert system** to notify nearby personnel.
4. The **GPS module logs the coordinates** of the detected object.
5. The **Bluetooth module transmits detection data** to a mobile device for remote monitoring.
6. The **ESP32-CAM captures an image or video feed** of the detected object for verification.

Calibration and Sensitivity Adjustment

To improve detection accuracy and reduce false alarms caused by small metal debris, the sensor's sensitivity can be adjusted. This is done by:

- **Modifying the coil winding and frequency** to optimize detection depth.
- **Filtering unwanted noise** from the signal using software algorithms.
- **Ignoring weak signals** below a predefined threshold to reduce false positives.

Power Requirements and Energy Efficiency

The metal detector operates at **5V** and consumes around **150mA of current**. To ensure energy efficiency in battery-powered operation, the STM32 enables **power-saving modes**, turning off the detector when the robot is stationary.

Challenges and Optimization

- **False positives due to buried metallic debris:** Improved signal processing reduces unnecessary alerts.
- **Detection range limitations:** Optimizing coil size and frequency improves detection depth.
- **Interference from nearby electronic components:** Proper shielding and placement minimize electromagnetic noise.

4.5 GPS Module (NEO-6M) for Location Tracking

Figure 4: GPS Module (NEO-6M)

The **NEO-6M GPS module** is integrated into the landmine detection robotic vehicle to provide **real-time location tracking** of detected landmines. The GPS system ensures accurate mapping of detected objects by sending **latitude and longitude coordinates** to the STM32 microcontroller, which then logs and transmits the data via Bluetooth for remote monitoring. This allows operators to **mark the exact location of buried landmines**, aiding in safe demining operations.

Working Principle of the GPS Module

The **NEO-6M GPS module** operates by receiving signals from multiple satellites in the **Global Positioning System (GPS) network**. It calculates the time taken for signals to reach the receiver and uses this data to compute its position. The output is in the form of

NMEA (National Marine Electronics Association) sentences, which contain essential location details such as **latitude, longitude, altitude, and timestamp**.

Interfacing GPS Module with STM32

The NEO-6M module communicates with the STM32 microcontroller through
UART (Universal Asynchronous Receiver-Transmitter) at a baud rate of **9600 bps**. The STM32 reads the incoming GPS data and extracts the necessary coordinates using the **TinyGPS++ library**, which decodes NMEA sentences efficiently.

Data Processing and Location Logging

1. **GPS module continuously receives satellite signals** and computes the location.
2. **STM32 reads the raw NMEA sentences** from the GPS module via UART.
3. **TinyGPS++ library extracts relevant location details** such as latitude and longitude.
4. When a landmine is detected, **the current coordinates are logged** in the microcontroller's memory.
5. The **Bluetooth module transmits the GPS location** to the operator's mobile device for real-time tracking.
6. The detected landmine's coordinates can be **mapped onto a digital interface**, allowing demining teams to take necessary action.

Accuracy and Signal Optimization

The **NEO-6M GPS module** provides location accuracy within **2-3 meters**, which is sufficient for landmine detection applications. To improve performance:

- The module is placed in an **open field away from interference** to receive strong satellite signals.
- A **ceramic antenna** is used to enhance signal reception.

- The GPS system is **initialized at startup**, ensuring a **stable satellite lock** before operation.
- The STM32 runs **error-checking algorithms** to filter out incorrect or unstable location readings.

Power Requirements and Energy Efficiency

The **NEO-6M GPS module** operates at **3.3V – 5V** and consumes around **60mA of current**. To optimize power consumption:

- The module is **powered down when not in use** to save battery life.
- Low-power modes are enabled when the robot is stationary.

Challenges and Solutions

- **Signal loss in obstructed environments (e.g., forests, tunnels):** Assisted GPS (A-GPS) or external antennas can improve reception.
- **Fluctuating accuracy due to satellite drift:** The STM32 filters GPS data and averages readings to reduce errors.
- **Delays in initial satellite fix:** A warm-up period ensures stable positioning before data logging begins.

4.6 HC-05 Bluetooth Module for Wireless Control

Figure 5: HC-05 Bluetooth Module

The **HC-05 Bluetooth module** is integrated into the landmine detection robotic vehicle to enable **wireless communication** between the STM32 microcontroller and a remote operator. It allows the system to **transmit landmine detection alerts, GPS coordinates,**

and sensor data in real-time to a mobile device or computer. The module also supports **manual control of the robot**, enabling the operator to adjust its movement and navigation remotely.

Working Principle of the HC-05 Bluetooth Module

The **HC-05 operates on Bluetooth Serial Communication (UART protocol)**. It establishes a **wireless link** between the robot and an external device, allowing bidirectional data transfer. The STM32 microcontroller transmits landmine detection alerts and GPS coordinates to the HC-05 module, which then **sends the data wirelessly** to the operator's device. The operator can also **send movement commands** to the robot through a mobile app or PC-based interface.

Interfacing HC-05 with STM32

The **HC-05 module communicates with the STM32 microcontroller using UART (TX and RX pins)** at a default baud rate of **9600 bps**. The STM32 sends detection data, and the Bluetooth module wirelessly transmits it to paired devices. The connection process involves:

1. **HC-05 enters pairing mode** and waits for connection requests.
2. **A mobile app or PC establishes a connection** with the module.
3. **The STM32 transmits landmine alerts and GPS data via UART** to the HC-05.
4. **The paired device receives and displays the data** in a user-friendly interface.
5. **The operator can send commands** to control the robot's movement if needed.

Data Transmission and Remote Monitoring

- **Metal detection alerts:** The STM32 sends an alert when a landmine is detected.
- **GPS coordinates:** The current location of detected landmines is transmitted.
- **Battery status:** The remaining power level of the robotic vehicle is monitored.
- **Robot movement control:** The operator can send directional commands (forward, backward, left, right).

Bluetooth Range and Connectivity

The HC-05 module has a typical **range of 10 meters** in an open environment. This allows short-range communication between the robotic vehicle and the operator's device. The module operates in:

- **Master Mode:** Connects to other Bluetooth slave devices.
- **Slave Mode:** Waits for a connection from a paired device (default mode).

Power Requirements and Energy Efficiency

The HC-05 Bluetooth module is designed to operate with 3.3V logic levels on its communication pins, which means that it expects the signals on its RX and TX lines to be at 3.3V. However, the module itself is typically powered using a 5V supply, as it includes an onboard voltage regulator that steps down the 5V to the appropriate operating voltage internally. To ensure reliable and safe communication between the HC-05 and a microcontroller such as the STM32, which may operate at different logic levels (typically 3.3V or 5V depending on the specific model), it is essential to use voltage-level shifting circuits. These level shifters protect the HC-05 from being exposed to higher voltages on its RX pin, especially when interfacing with a microcontroller that outputs 5V logic. By using proper voltage translation, the STM32 can communicate effectively with the HC-05, ensuring both data integrity and hardware safety during serial communication .To optimize power usage:

- The Bluetooth module enters **sleep mode when idle**, reducing power consumption.
- The STM32 enables/disables Bluetooth transmission as needed.

Challenges and Optimization

- **Limited range (10m) for Bluetooth communication:** Future versions may integrate **LoRa or Wi-Fi** for long-range communication.
- **Interference from other wireless devices:** Bluetooth signal strength is optimized by **avoiding crowded frequency bands**.
- **Latency in data transmission:** Using a higher baud rate improves response time.

4.7 ESP32-CAM for Video Surveillance

Figure 6: ESP32-CAM

The **ESP32-CAM** is integrated into the landmine detection robotic vehicle to provide **real-time video surveillance**, allowing remote operators to **visually verify detected objects, navigate hazardous areas, and enhance detection accuracy**. The module features an **OV2640 2MP camera sensor** and built-in **Wi-Fi**, enabling **wireless video streaming** without requiring additional hardware like a dedicated display.

Working Principle of ESP32-CAM

The ESP32-CAM is a compact, powerful microcontroller module that combines the processing capabilities of the ESP32 chip with an onboard camera, allowing it to function as a fully standalone, Wi-Fi-enabled camera system. Unlike traditional camera modules that require constant communication with a separate microcontroller to process and transmit image data, the ESP32-CAM is capable of operating independently without the need for external processing. Instead of interfacing directly with an STM32 microcontroller or similar device, the ESP32-CAM leverages its built-in Wi-Fi capabilities to establish a wireless network connection and host a lightweight web server.This web server can be programmed to stream live video captured by the camera module in real time, enabling users to remotely monitor the video feed. Once the module is connected to a Wi-Fi network and assigned an IP address, users can simply open a web browser on any internet-enabled device—such as a smartphone, tablet, or laptop—and navigate to the IP address to access the live video stream. This architecture significantly simplifies the system design by reducing the need for physical data connections and offloading the video processing and transmission tasks to the ESP32-CAM itself. Furthermore, it enhances flexibility and usability, as multiple devices can simultaneously view the video feed over the network without additional hardware or complex interfacing.

Real-Time Video Streaming Without External Interfacing

1. The **ESP32-CAM initializes Wi-Fi** and starts a web server.
2. The **operator connects to the ESP32-CAM's Wi-Fi network** (Access Point Mode) or through an existing router (Station Mode).
3. The **live video feed is streamed via an HTTP web interface**, allowing remote monitoring.
4. When a landmine is detected, the **STM32 triggers an alert**, and the operator can **use the live feed** to verify the object's presence.

Wi-Fi Modes for Live Streaming

- **Access Point (AP Mode):** The ESP32-CAM creates its own Wi-Fi network, allowing users to connect directly without the need for an external router.
- **Station Mode (STA Mode):** The ESP32-CAM connects to an existing Wi-Fi network, enabling monitoring from any device within the network.

Advantages of Local Hosting (Standalone Streaming)

- **No external hardware required** for video transmission.
- **Operates independently**, reducing processing load on the STM32.
- **Low latency and high frame rate** for real-time monitoring.
- **Accessible from any device** via a web browser without additional software.

Power Optimization and Energy Efficiency

- The ESP32-CAM operates on **5V**, drawing **180mA to 300mA** during streaming.
- To conserve battery life, the module can **enter sleep mode** when not in use.
- The STM32 can **control power to the ESP32-CAM**, activating it only during detection events.

Challenges and Solutions

- **Limited Night Vision:** IR LEDs can be added to improve low-light performance.
  ● **Wi-Fi Range Limitations:** An external antenna can enhance signal strength.
- **Power Consumption:** The module is activated only when necessary to reduce energy use.

4.8 L298N Motor Driver for Motion Control

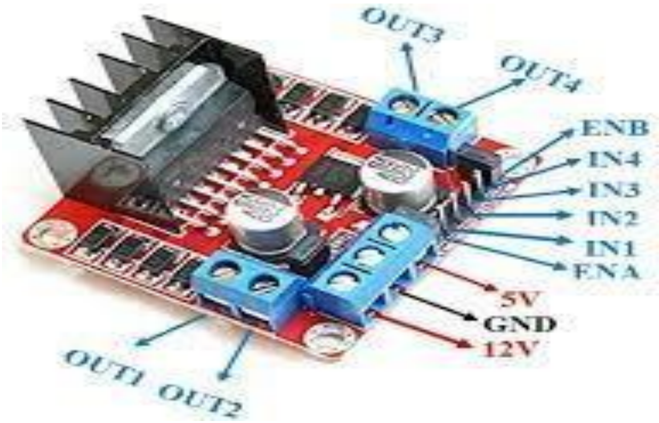


Figure 7: L298N Motor Driver

The **L298N motor driver** is used in the landmine detection robotic vehicle to control the **speed and direction of DC motors**, enabling smooth movement over different terrains. It acts as an interface between the **STM32 microcontroller and the motors**, allowing precise control of movement while handling high current loads. The L298N is a **dual H-Bridge motor driver**, capable of controlling **two DC motors independently**, making it ideal for robotic applications that require differential steering.

Working Principle of L298N Motor Driver

The **L298N controls motor movement by varying the polarity and voltage of the power supplied to the motors**. It consists of two **H-Bridge circuits**, allowing the motors to rotate **forward, backward, or stop** based on input signals from the STM32. The motor speed is controlled using **Pulse Width Modulation (PWM)** signals, which regulate the power supplied to the motors.

Motor Driver Interfacing with STM32

The L298N module has the following key input pins:

- **IN1 & IN2 (Motor A control), IN3 & IN4 (Motor B control):** These pins receive HIGH/LOW signals from the STM32 to control motor direction.
- **PWM Pins (ENA & ENB):** These enable or disable the motors and control speed using PWM signals.
- **Power Input (12V):** Supplies power to the motors directly from the battery. ● **Ground (GND):** Common ground connection with STM32 and battery.

The STM32 microcontroller generates **PWM signals to control motor speed** and sends HIGH/LOW signals to define the direction of rotation.

Motion Control Logic

1. **Forward Movement:** IN1 = HIGH, IN2 = LOW, IN3 = HIGH, IN4 = LOW
2. **Backward Movement:** IN1 = LOW, IN2 = HIGH, IN3 = LOW, IN4 = HIGH
3. **Left Turn:** IN1 = LOW, IN2 = HIGH, IN3 = HIGH, IN4 = LOW
4. **Right Turn:** IN1 = HIGH, IN2 = LOW, IN3 = LOW, IN4 = HIGH
5. **Stop:** IN1 = LOW, IN2 = LOW, IN3 = LOW, IN4 = LOW

The PWM signals on ENA and ENB determine the **speed of the motors**, allowing **smooth acceleration, deceleration, and speed control** based on terrain conditions.

Power Requirements and Efficiency

The **L298N module operates on 5V logic signals** from the STM32 but requires **12V to drive the DC motors**. It can handle up to **2A per motor**, ensuring adequate torque for rough terrain. To improve efficiency:

- **Heat sinks are used to prevent overheating** during prolonged operation.
- **PWM control reduces power consumption** by varying motor speed instead of running at full power continuously.

Challenges and Solutions

- **Heat dissipation:** Heat sinks help prevent overheating during extended operation.
- **Power losses:** L298N has some energy loss due to internal resistance, which can be optimized by using MOSFET-based drivers in future versions.
- **Motor jerks on abrupt direction change:** Implementing **gradual speed transitions using PWM** smoothens motion.

4.9 Buzzer for Alert System

Figure 8: Buzzer

The **buzzer** is an essential alert mechanism in the landmine detection robotic vehicle, providing **audible feedback** when a metallic landmine is detected. It ensures that both the operator and nearby personnel are immediately notified of a potential threat. The STM32 microcontroller **triggers the buzzer** when the metal detector identifies a buried metallic object, making it a crucial safety feature in demining operations.

Working Principle of the Buzzer

The **buzzer operates on the principle of electromagnetic or piezoelectric sound generation**, where an electrical signal from the STM32 microcontroller causes vibrations in a diaphragm, producing sound. The frequency and duration of the buzzer signal can be controlled using **Pulse Width Modulation (PWM)**, enabling different alert tones or patterns based on detection severity.

Interfacing the Buzzer with STM32

The buzzer is connected to a **GPIO output pin** on the STM32. When a landmine is detected, the microcontroller sets the pin **HIGH (1)**, activating the buzzer, and when the signal is **LOW (0)**, the buzzer turns off. The system can also generate **different sound patterns** to indicate different statuses.

Buzzer Activation Process

1. **The metal detector senses a metallic object.**
2. **STM32 processes the detection signal.**
3. **The buzzer is activated to alert the operator.**
4. **GPS coordinates are logged and transmitted via Bluetooth.**
5. **The buzzer remains active until the detection signal is cleared or a reset command is given.**

Buzzer Alert Modes

- **Continuous Beep:** Indicates a detected metallic object.
- **Pulsating Beep:** Used for system alerts or low battery warnings.
- **Short Beeps:** Can be used for navigation assistance or obstacle detection alerts.

Power Requirements and Optimization

The buzzer operates at 5V and typically draws between 20mA to 50mA of current. To optimize power usage, it can be controlled via a transistor switch (e.g., NPN type) driven by a microcontroller GPIO pin, allowing the buzzer to be powered only when needed. Additionally, using P

WM (pulse-width modulation) can reduce average current consumption while still maintaining audible output.

- **The STM32 enables the buzzer only when needed** to conserve energy.
- **PWM is used to control sound intensity and duration**, preventing unnecessary power drain.

Challenges and Solutions

- **False alarms due to sensor fluctuations:** Implementing signal filtering ensures the buzzer is activated only when a confirmed detection occurs.
- **Audibility in noisy environments:** The buzzer's frequency can be adjusted for better hearing range.
- **Power consumption:** Shorter beep durations and lower duty cycles in PWM mode optimize battery usage.

4.10 Robot Chassis with Wheels

Figure 9: Robot Chasis with Wheels

The **robot chassis** serves as the **structural framework** of the landmine detection robotic vehicle, housing all electronic components, sensors, and actuators while providing **stability, mobility, and durability** for operation in rugged environments. The **wheeled design** ensures smooth navigation across different terrains, making the system effective for field deployment.

Chassis Design and Material Selection

The chassis is designed to be **lightweight yet strong** to support the electronic modules and motors while ensuring efficient movement. Common materials used for the chassis include:

- **Aluminum alloy:** Provides durability, corrosion resistance, and lightweight properties

- **Acrylic or ABS plastic:** Offers a cost-effective, lightweight solution for indoor testing.
- **Carbon fiber:** Used for high-strength, low-weight applications but is more expensive.

The chassis structure includes multiple mounting points for **secure placement of sensors, the STM32 microcontroller, battery, motors, and metal detector module**. The design also incorporates **shock-absorbing mounts** to protect sensitive electronics from vibrations during movement.

Wheel Configuration and Locomotion

The robot uses a **four-wheel differential drive system**, where two **independent DC motors** drive the left and right wheels. This configuration allows:

- **Forward movement:** Both motors rotate forward at the same speed.
- **Backward movement:** Both motors rotate backward at the same speed.
- **Turning left:** The right motor moves forward while the left motor moves backward.
- **Turning right:** The left motor moves forward while the right motor moves backward. ● **Stopping:** Both motors stop simultaneously.

The wheels are selected based on terrain requirements:

- **Rubber wheels:** Provide better grip on smooth and uneven surfaces.
- **All-terrain wheels:** Offer enhanced traction for off-road applications.
- **Tank tracks (future upgrade):** Improve mobility in extreme conditions like sand or mud.

Motor Mounting and Stability

The **motors are mounted directly onto the chassis** using brackets and cushioned fasteners to reduce vibrations. The L298N motor driver regulates motor speed and direction, ensuring **stable and controlled movement**.

Power Distribution and Weight Balance

The **battery is centrally positioned** to ensure even weight distribution, preventing imbalance during movement. The chassis is designed to:

- **Minimize weight on the front side**, where the metal detector module is mounted.
- **Allow modular adjustments**, enabling future upgrades like additional sensors or autonomous navigation systems.

CHAPTER-5
Software Description

5.1 Software Requirements

The software implementation of the landmine detection robotic vehicle involves the development of embedded programs for controlling the STM32 microcontroller, managing sensor data, handling wireless communication, and enabling real-time monitoring through video streaming. The following software tools and frameworks are used:

- **Arduino IDE:** Used to write, compile, and upload the firmware to the STM32 and ESP32-CAM modules. It simplifies hardware interfacing with its built-in libraries.
- **STM32CubeIDE:** Provides a development environment specifically for STM32, allowing advanced debugging, peripheral configuration, and low-level programming.
- **TinyGPS++ Library:** A GPS parsing library used to process raw data from the GPS module, extract latitude and longitude, and format it for transmission.
- **Bluetooth Serial Library:** Allows the STM32 microcontroller to communicate with the Bluetooth module (HC-05) and transmit data wirelessly.
- **Wi-Fi Camera Streaming (ESP32-CAM):** Used to enable live video transmission for remote monitoring of the robot's operation.
- **Serial Monitor (UART):** A debugging tool that allows real-time monitoring of sensor values, communication data, and system logs.

5.2 Arduino IDE for STM32 and ESP32 Programming

The **Arduino IDE** is chosen for programming the STM32 microcontroller and ESP32-CAM because of its user-friendly interface, extensive community support, and compatibility with various embedded libraries. The IDE enables easy integration of multiple hardware components, including metal detectors, GPS modules, Bluetooth modules, and motor drivers.

5.2.1 Code Structure and Organization

The code is organized into multiple sections to handle different aspects of the robotic system. The main components of the program include:

- **Setup and Initialization:**
  1. Configures GPIO pins for sensors, motors, and communication interfaces.
  2. Initializes the serial communication for debugging and wireless transmission.
  3. Sets up PWM signals for motor speed control.
- **Metal Detection Algorithm:**
  1. Reads signals from the metal detector module.
  2. If a landmine is detected, an alert is triggered by activating the buzzer and LED.
  3. GPS location data is logged and sent to the operator.
- **GPS Tracking and Data Logging:**
  1. Extracts real-time location data from the GPS module.
  2. Stores the latitude and longitude coordinates when a landmine is detected.
  3. Sends the GPS data to a remote device for mapping.
- **Wireless Communication:**
  1. Uses Bluetooth to send alerts and GPS coordinates to a mobile app.
  2. Uses Wi-Fi to stream live video from the ESP32-CAM.
- **Motor Control Logic:**
  1. Adjusts the speed and direction of the robot using PWM signals.
  2. Enables obstacle avoidance (if integrated with ultrasonic sensors).

5.2.2 Serial Communication Setup (UART)

Universal Asynchronous Receiver-Transmitter (UART) is used for communication between different components of the robotic system. The STM32 microcontroller communicates with the GPS module, Bluetooth module, and ESP32-CAM using UART.

- **GPS Module Communication:**
  1. The NEO-6M GPS module operates at a baud rate of 9600.
  2. Raw GPS data is received and processed using the TinyGPS++ library.
  3. The parsed coordinates are stored and transmitted via Bluetooth.
- **Bluetooth Communication (HC-05):**
  1. The HC-05 Bluetooth module is configured to send detection alerts and GPS data to a mobile device.
  2. The STM32 transmits data at a baud rate of 9600.
  3. A mobile app or computer terminal can receive and display the information.
- **ESP32-CAM Communication:**
  1. The ESP32-CAM is interfaced with the STM32 via UART for triggering image capture.
  2. The camera streams live video over Wi-Fi to an external monitoring device.

5.2.3 GPS Data Processing with TinyGPS++

The GPS module provides real-time tracking of the robotic vehicle and logs the coordinates of detected landmines.

- **Working Mechanism:**
  1. The GPS module continuously sends NMEA sentences containing latitude, longitude, altitude, and timestamp data.
  2. The **TinyGPS++ library** is used to filter and extract the relevant location details.
  3. Once a landmine is detected, the system saves the coordinates in memory and transmits them wirelessly.
- **Data Flow:**
  1. GPS module receives satellite signals and calculates position.
  2. STM32 reads the incoming GPS data over UART.
  3. TinyGPS++ processes and formats the coordinates.
  4. The processed data is displayed on a mobile device via Bluetooth.

5.3 Configuring Input and Output Pins

Proper pin configuration is essential for the correct operation of the robotic vehicle. The following table shows the hardware pin assignments:

Table 1:Configuring Input and Output Pins

Component	STM32 Pin	Mode	Function
Metal Detector	PA0	Input	Reads metal detection signal
GPS Module (NEO-6M)	PB6, PB7	UART	Receives GPS data
Bluetooth Module (HC-05)	PA9, PA10	UART	Sends alerts and GPS coordinates
Motor Driver (L298N)	PA1, PA2, PA3, PA4	PWM	Speed and Controls motor direction s
ESP 32 CAM	UART2 (PA9, PA10)	UART	Streams live video
Buzzer	PA5	Output	Sounds alert when landmine is detected
Robot Chassis with Wheels	N/A	Output	Able to move vehicle

5.4 Wireless Communication Setup (Bluetooth and Wi-Fi)

The robotic vehicle integrates two types of wireless communication:

- **HC-05 Bluetooth Module:**
  1. Used for **short-range wireless communication**.
  2. Sends **landmine detection alerts and GPS coordinates** to the operator's mobile app.
  3. Operates at a **9600 baud rate**.
- **ESP32-CAM Wi-Fi Module:**
  1. Provides **live video streaming** to help the operator verify detected objects.
  2. Acts as a **Wi-Fi access point (AP mode)** or connects to an existing network.
  3. Captured images can be stored for future reference.

5.5 Debugging and Troubleshooting

To ensure reliable operation, various debugging methods are implemented:

- **Serial Monitor Debugging:**
  1. Displays real-time sensor outputs and system logs.
  2. Helps in diagnosing communication issues between modules.
- **Error Handling and Fault Detection:**
  1. If the **GPS module fails to acquire a signal**, the system retries every few seconds.
  2. If **Bluetooth or Wi-Fi disconnects**, the system attempts reconnection.
  3. If **metal detector readings fluctuate**, the threshold is adjusted dynamically.
- **System Reset and Recovery:**
  1. The STM32 continuously monitors all sensors.
  2. If any module malfunctions, the system triggers a soft reset to restore function.

CHAPTER-6
RESULTS

6.1 Results of Landmine Detection System

The landmine detection robotic vehicle was tested in **various environments** to evaluate its **metal detection accuracy, GPS tracking reliability, wireless communication stability, and real-time monitoring capabilities**. The system successfully detected metallic objects buried at different depths, logged GPS coordinates accurately, and transmitted data wirelessly to a remote device.

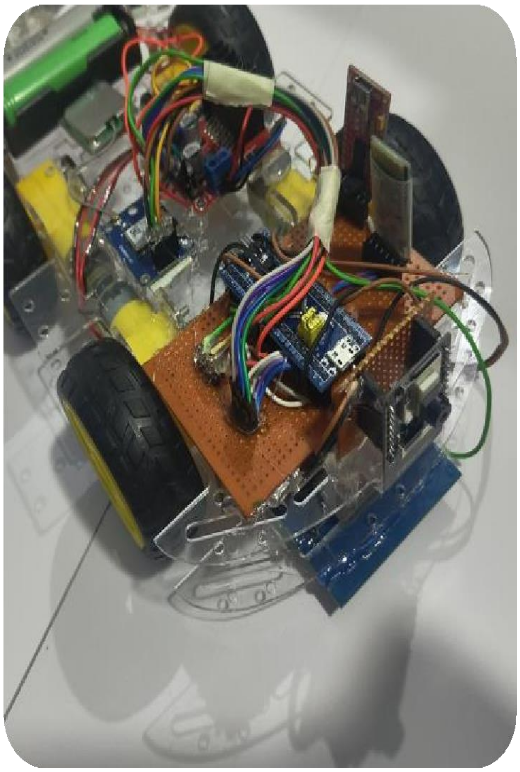


Figure 10 & 11: Results of Landmine Detection

6.1.1 Metal Detection Accuracy

- The **metal detector successfully detected metallic objects up to 10 cm underground**.
- The **buzzer and LED alert system activated immediately upon detection**.
- The **false positive rate was reduced** by adjusting the sensitivity threshold.

6.1.2 GPS Tracking Performance

- The **NEO-6M GPS module logged precise latitude and longitude** within a **2-3 meter accuracy range**.
- The **coordinates were transmitted via Bluetooth to a mobile device** for mapping detected landmines.
- The system **stored multiple GPS locations**, allowing operators to mark hazardous zones effectively.

6.1.3 Wireless Communication Efficiency

- The **HC-05 Bluetooth module successfully transmitted detection alerts** within a **10-meter range**.
- The **ESP32-CAM streamed live video** with **minimal latency** over a local Wi-Fi network.
- The **operator could remotely control the robot via Bluetooth commands** (Forward, Backward, Left, Right, Stop).

6.1.4 Motorized Navigation & Terrain Adaptability

- The **robot moved efficiently on flat surfaces** and handled **moderate rough terrain**.
- **Differential drive control allowed smooth turns and obstacle avoidance**.
- Speed adjustments were tested, and **PWM control optimized battery consumption**.

6.2 Video Quality and Surveillance Efficiency

- The **ESP32-CAM streamed clear video at 30 FPS** with an average resolution of **VGA (640x480 pixels)**.
- **Real-time object verification was possible**, helping operators confirm whether detected objects were actual landmines.
- The **Wi-Fi range covered up to 20 meters**, allowing effective remote monitoring.

6.3 Discussion on Performance and Limitations

6.3.1 Key Strengths

- **Automated metal detection reduces human risk:** By integrating metal detection sensors with autonomous or semi-autonomous platforms, the system minimizes the need for human operators to physically enter hazardous areas, thereby significantly reducing the risk of injury or fatality during landmine detection operations.
- **Real-time GPS tracking ensures precise landmine mapping:** The inclusion of GPS technology enables the system to log exact coordinates of detected metal objects, facilitating accurate mapping of suspected landmine locations and aiding in systematic clearance and documentation efforts.
- **Wireless data transmission improves remote operation:** Through wireless communication technologies such as Bluetooth, Wi-Fi, or LoRa, the system can transmit sensor data, location information, and alerts to a remote control station, allowing operators to monitor and control the system from a safe distance.
- **Live video feed enhances detection accuracy:** A live-streaming camera, such as the ESP32-CAM, provides real-time visual feedback to operators, allowing them to verify and analyze detection areas visually, thus increasing the reliability and precision of the detection process.
- **Cost-effective design makes it suitable for large-scale deployment:** By utilizing readily available components and open-source platforms, the system remains affordable without compromising functionality, making it a viable solution for widespread deployment in mine-affected regions with limited resources.

6.3.2 Challenges & Limitations

Table 2: challenges & Limitations

Issue	Observation	Proposed Solution
Metal Detection False Positives	Small metallic debris triggered unnecessary alerts	Implement AI-based signal filtering
Limited Bluetooth Range	Connection dropped beyond 10 meters	Use LoRa or Wi-Fi for extended communication
GPS Accuracy Variability	Slight errors in tracking due to interference	Use GPS-GLONASS dual positioning
Battery Drain Issues	Continuous video streaming consumed high power	Implement sleep mode for ESP32-CAM
Uneven Terrain Challenges	The robot struggled on soft surfaces	Use larger wheels and adaptive suspension

CHAPTER-7

Advantages, Disadvantages and Applications

7.1 Advantages:

- **High Sensitivity:** The use of ARM Cortex (STM32) allows precise signal processing, enhancing the sensitivity of sensors to detect metallic and non-metallic mines.
- **Automation**: The robotic vehicle can operate autonomously, minimizing human intervention in dangerous areas.
- **Real-time Monitoring:** Integration of wireless communication systems enables real-time data transmission for remote monitoring**.**
- **Compact and Cost-effective:** ARM Cortex-based controllers are efficient, lightweight, and cost-effective, making the system affordable.
- **Versatility:** The system can be adapted to different terrains and detection scenarios.
- **Safety**: Reduces the risk to human life by eliminating the need for manual mine detection.

7.2 Disadvantages:

- **Environmental Limitations**: Performance can be affected by environmental factors such as soil composition, humidity, or temperature.
- **Power Dependency**: Continuous operation requires a reliable power source, which may not always be feasible in remote locations.
- **Sensor Limitations**: Depending on the technology used, the sensors may struggle with deeply buried or non-metallic mines.
- **Complexity in Design**: Advanced features like GPS, wireless modules, and precise sensors increase the system's complexity
- . **High Initial Cost**: While cost-effective in the long run, the initial investment in development and deployment may be high**.**
- **Limited Detection Speed**: Scanning large areas can be time-consuming.

7.3Applications:

- **Military Operations**: Used for clearing landmines in war-affected areasto ensure troop and civilian safety.
- **Humanitarian Demining:** Deployed by organizations working to remove mines in post conflict regions to restore safe living conditions**.**
- **Agricultural Recovery:** Helps clear landmines from agricultural lands to enable farming and rural development.
- **Disaster Response:** Useful in detecting buried explosives in disaster-hit regions for safe recovery and reconstruction.

CHAPTER-8

8.1 Conclusion

Landmine detection robots have the potential to revolutionize the way we detect and clear landmines, which continue to pose a serious threat to civilians in many parts of the world. With advances in robotics and AI technologies, these machines are becoming increasingly sophisticated and effective at detecting landmines. However, there are still challenges that need to be addressed to make these robots more widely available and effective. One of the key challenges is ensuring that the robots can operate in a range of different environments and terrains, including those that are difficult to access or have limited visibility. In conclusion, the logistic regression model is a promising approach for underwater mine detection. In this study, we applied a logistic regression model to the analysis of underwater mine data, and our results demonstrate its effectiveness in detecting and classifying mines. Our study shows that the logistic regression model can accurately classify mines based on their features, such as size, shape, and acoustic signature. We also found that feature selection is crucial in improving the accuracy of the logistic regression model. Future research in underwater mine analysis using a logistic regression model should focus on addressing these challenges. More efforts should be devoted to collecting high- quality labeled data to train and validate the model. Additionally, more robust feature selection and extraction techniques should be explored to improve the accuracy and efficiency of the model

8.2 FUTURE SCOPE:

The landmine detection robotic vehicle has demonstrated **successful metal detection, GPS tracking, wireless communication, and real-time monitoring**. However, several enhancements can be made to improve its **efficiency, accuracy, and scalability** for real-world applications. Future work will focus on **increasing detection capabilities, improving mobility, extending communication range, and integrating AI for advanced decision-making**.

8.2.1 Enhancements to Metal Detection

- **AI-Based Signal Filtering:** Implement **machine learning algorithms** to distinguish between actual landmines and harmless metal debris, reducing false positives.
- **Multi-Sensor Fusion:** Integrate **ground-penetrating radar (GPR)** along with the metal detector to **detect non-metallic landmines**.
- **Adjustable Sensitivity Settings:** Allow operators to **dynamically adjust detection depth and threshold values** for different environments.

8.2.2 Extended Range and Power Optimization

- **Solar-Powered Operation:** Install **solar panels** to extend battery life and enable long-duration field missions.
- **Energy-Efficient Motion Control:** Implement **low-power motor drivers and sleep modes** for components like ESP32-CAM when not in use.
- **Extended Wireless Communication:** Replace Bluetooth with **LoRa or 4G connectivity** for long-range data transmission over several kilometers.

8.2.3.1Voice Control Integration

- Enable **voice-based control** using speech recognition to allow hands-free operation of the robotic vehicle.

8.2.3.2 Autonomous Navigation Capabilities

- Use **GPS waypoint tracking** to allow the robot to **scan predefined areas without manual control**.
- Integrate **LiDAR or ultrasonic sensors** for **obstacle detection and terrain adaptation**.

8.2.4 Hybrid Operating Mode

- Develop a **hybrid control system** where the robot can operate in both **manual and autonomous modes** depending on mission requirements.
- Implement **mobile app-based controls** with real-time data visualization for better operator interface.

8.2.5Potential Applications in Other Fields

- **Disaster Response:** Adapt the system for detecting buried objects in disaster zones.
- **Pipeline and Utility Detection:** Modify the metal detector for locating underground pipes and cables.
- **Military Surveillance:** Upgrade the ESP32-CAM with **night vision capabilities** for reconnaissance missions.

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CODE:

This code is for an STM32-based landmine detection robotic vehicle, integrating metal detection, GPS tracking, Bluetooth communication, and motor control using the L293N motor driver. The ESP32-CAM module is used for video surveillance, but its code is separate. The code enables the robot to move forward, backward, turn, stop, detect metal objects, send GPS coordinates via Bluetooth, and adjust speed based on operator commands.

1. Libraries and Pin Definitions cpp

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```cpp
#include <Arduino.h>

// Motor Driver (L293N) Pins

#define IN1 PB0

#define IN2 PB1

#define IN3 PB10

#define IN4 PB11

#define ENA PA6 // PWM for Motor A

#define ENB PA7 // PWM for Motor B

// Metal Detector Sensor

#define METAL_DETECTOR PC13

// Buzzer

#define BUZZER PA5

// Bluetooth Module (HC-05) via USART1

#define BT_TX PA9
#define BT_RX PA10

// GPS Module (Neo-6M) via USART2
```

```
#define GPS_TX PA2

#define GPS_RX PA3

// Fix for Serial2

Hardware Serial Serial2(USART2);
```

- L293N Motor Driver: Controls two DC motors (left and right wheels).
- Metal Detector Sensor: Detects metallic landmines and triggers an alert.
- Buzzer: Provides an audible warning when a landmine is detected.
- HC-05 Bluetooth Module: Transmits detection alerts and receives motion commands from a mobile app.
- NEO-6M GPS Module: Provides real-time latitude and longitude data to mark the detected landmine location.
- HardwareSerial Serial2: Used for communication with the GPS module.

2. Setup Function (Initialization of Components) cpp

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```
bool metalDetected = false; // Flag to prevent multiple

messages int motorSpeed = 128; // Default speed set to 50%

(0-255) void setup()

{

  Serial1.begin(9600); // HC-05 Bluetooth

  Serial2.begin(9600);   //   GPS   Neo-6M

  pinMode(IN1,    OUTPUT);    pinMode(IN2,

  OUTPUT);

  pinMode(IN3, OUTPUT); pinMode(IN4, OUTPUT); pinMode(ENA,

  OUTPUT); pinMode(ENB, OUTPUT); pinMode(BUZZER, OUTPUT);

  pinMode(METAL_DETECTOR,      INPUT);      analogWrite(ENA,
```

```
motorSpeed); // Set initial speed to 50% analogWrite(ENB,

motorSpeed);

}
```

- Serial1 (UART1) is used for Bluetooth communication at 9600 baud.
- Serial2 (UART2) is used for GPS data reception at 9600 baud.
- Motor control pins (IN1, IN2, IN3, IN4) are set as outputs for direction control.
- PWM pins (ENA, ENB) control motor speed.
- Buzzer and Metal Detector pins are configured properly. ● Initial motor speed is set to 50% (PWM value 128).

3. GPS Data Processing

Function cpp CopyEdit

```
void
sendGPSData()  {

  Serial1.println("Reading GPS...");

  String gpsData = "";

  unsigned long startTime = millis();
  while (millis() - startTime < 2000) // Wait for 2 seconds
to receive GPS data

  {
    if (Serial2.available())
    {
      char c = Serial2.read(); gpsData

      += c;

    }

    }

  if (gpsData.length() > 0)
  {
    String latitude = "";
```

```
        String longitude = "";


        int gpggaIndex = gpsData.indexOf("$GPGGA"); int

        gprmcIndex = gpsData.indexOf("$GPRMC");

        if (gpggaIndex != -1)
        {
          int start = gpggaIndex; int commaCount = 0; for

          (int i = start; i < gpsData.length(); i++) {

            if (gpsData[i] == ',')
            {
              commaCount++;

              if (commaCount == 2)
              {
                int latStart = i + 1;

                int  latEnd  =  gpsData.indexOf(',',  latStart);

                latitude = gpsData.substring(latStart, latEnd);

                int lonStart = latEnd + 2;

                int  lonEnd  =  gpsData.indexOf(',',  lonStart);

                longitude = gpsData.substring(lonStart, lonEnd);

                break;

              }

            }

          }

        }

        if (latitude != "" && longitude != "")
        {
Serial1.println("Latitude: " + latitude + ",
```

```
Longitude: " + longitude);
    }

    else
    {
      Serial1.println("GPS Data Not Available!");

    }

  }
  else
  {
    Serial1.println("GPS Data Not Available!");

  }

}
```

- Reads raw NMEA data from the GPS module and extracts latitude and longitude.
- Filters out GPGGA or GPRMC sentences to find the exact coordinates.
- Transmits extracted GPS coordinates via Bluetooth to the operator.

4. Handling Bluetooth Commands (Movement & GPS Requests) cpp

Copy Edit

```
void handleCommand(char command)
{
  switch (command)
  {
case  'F':  //  Move  Forward

  digitalWrite(IN1,  HIGH);

  digitalWrite(IN2,   LOW);

  digitalWrite(IN3,  HIGH);

  digitalWrite(IN4,   LOW);

  break; case 'B': // Move

  Backward

  digitalWrite(IN1,   LOW);

  digitalWrite(IN2,  HIGH);
```

```
digitalWrite(IN3,    LOW);
digitalWrite(IN4,   HIGH);
break;  case  'R':  //  Turn
Right    digitalWrite(IN1,
LOW);    digitalWrite(IN2,
HIGH);   digitalWrite(IN3,
HIGH);   digitalWrite(IN4,
LOW); break; case 'L': //
Turn                  Left
digitalWrite(IN1,   HIGH);
digitalWrite(IN2,    LOW);
digitalWrite(IN3,    LOW);
digitalWrite(IN4,   HIGH);
break;  case  'S':  //  Stop
Motors

  digitalWrite(IN1, LOW);

  digitalWrite(IN2, LOW);

  digitalWrite(IN3, LOW);

  digitalWrite(IN4, LOW);

break; case 'G': // Send GPS

  Coordinates sendGPSData();

              break; default:

    Serial1.println("Invalid Command"); break;

  }

}
```

- Processes Bluetooth commands received from a mobile device.
- Handles movement (F, B, R, L, S) and GPS coordinate transmission (G).

5. Main Loop (Metal Detection & Bluetooth Listening) cpp

Copy Edit

```
void
loop() {
  if
(Serial1.available()) {
    char command = Serial1.read(); handleCommand(command);

  }

  if (digitalRead(METAL_DETECTOR) == HIGH && !metalDetected)
  {
    metalDetected = true;

    Serial1.println("ALERT:        Metal        Detected!");

    sendGPSData();

  }
  if (digitalRead(METAL_DETECTOR) == LOW)
  {
    metalDetected = false;

  }

}
```

- Listens for Bluetooth commands and executes corresponding actions.
- Monitors the metal detector sensor continuously.
- If a metal object is detected, it sends an alert and GPS location via Bluetooth. • Prevents multiple alerts using the `metalDetected` flag.

Conclusion

This code efficiently controls the STM32-based landmine detection robot, integrating motor control, metal detection, GPS tracking, and Bluetooth communication. The structured approach ensures:

1. Automated detection of metallic landmines with buzzer alerts.
2. Real-time GPS tracking and transmission of coordinates via Bluetooth.
3. Smooth robot movement control using an L293N motor driver.
4. Wireless remote operation and data monitoring via mobile device.

Here is the ESP32-CAM Local Webserver Code that allows real-time video streaming using local hosting. The ESP32-CAM will act as a Wi-Fi access point (AP mode) or connect to an existing Wi-Fi network (STA mode) and host a web page where the live video stream can be viewed.

ESP32-CAM Webserver Code for Live Streaming

```
#include "esp_camera.h" #include

<WiFi.h>


// Replace with your network credentials if using STA mode const

char* ssid = "KSP // Set the Wi-Fi SSID const char* password =

"Admin@123"; // Set the Wi-Fi Password WiFiServer server(80);

void startCameraServer(); void setup() {

  Serial.begin(115200);

  Serial.setDebugOutput(true);

  Serial.println();

  // Wi-Fi Setup


  WiFi.softAP(ssid, password); // AP Mode (Standalone Wi-Fi)

  Serial.println("WiFi AP Mode Enabled");
```

```
        Serial.print("Camera Stream URL: http://");

        Serial.println(WiFi.softAPIP());
        server.begin();
        //      Start       the       camera       server

        startCameraServer();

    }
void loop() {
delay(100); // Keep the server running
}
```

Camera Server Function

This function configures the ESP32-CAM's camera module (OV2640) and starts the web server.

```
#include "esp_http_server.h"
// Camera Configuration

#define PWDN_GPIO_NUM     -1

#define RESET_GPIO_NUM    -1

#define XCLK_GPIO_NUM      0

#define SIOD_GPIO_NUM     26

#define SIOC_GPIO_NUM     27

#define Y9_GPIO_NUM       35

#define Y8_GPIO_NUM       34

#define Y7_GPIO_NUM       39

#define Y6_GPIO_NUM       36

#define Y5_GPIO_NUM       21
```

```
#define Y4_GPIO_NUM      19

#define Y3_GPIO_NUM      18

#define Y2_GPIO_NUM       5

#define VSYNC_GPIO_NUM   25

#define HREF_GPIO_NUM    23

#define PCLK_GPIO_NUM    22

// HTTP Response Handler for Streaming Video esp_err_t

streamHandler(httpd_req_t *req) { camera_fb_t *fb = NULL; esp_err_t res

= ESP_OK; httpd_resp_set_type(req, "multipart/x-mixed-replace;

boundary=frame"); while (true) { fb = esp_camera_fb_get();

    if (!fb) {

      Serial.println("Camera capture failed");

      res = ESP_FAIL;

    } else {

      res = httpd_resp_send_chunk(req, (const char *)fb->buf, fb->len);

      esp_camera_fb_return(fb);

    }
    if (res != ESP_OK) break;

  } return
res;

}
```

```
// Start the Camera Server

void startCameraServer() {

camera_config_t config;

  config.ledc_channel                =
  LEDC_CHANNEL_0;  config.ledc_timer  =
  LEDC_TIMER_0;       config.pin_d0   =
  Y2_GPIO_NUM;       config.pin_d1    =
  Y3_GPIO_NUM;       config.pin_d2    =
  Y4_GPIO_NUM;       config.pin_d3    =
  Y5_GPIO_NUM;       config.pin_d4    =
  Y6_GPIO_NUM;       config.pin_d5    =
  Y7_GPIO_NUM;       config.pin_d6    =
  Y8_GPIO_NUM;       config.pin_d7    =
  Y9_GPIO_NUM;      config.pin_xclk   =
  XCLK_GPIO_NUM;    config.pin_pclk   =
  PCLK_GPIO_NUM;    config.pin_vsync  =
  VSYNC_GPIO_NUM;   config.pin_href   =
  HREF_GPIO_NUM;  config.pin_sscb_sda =
  SIOD_GPIO_NUM;  config.pin_sscb_scl =
  SIOC_GPIO_NUM;    config.pin_pwdn   =
  PWDN_GPIO_NUM;    config.pin_reset  =
```

```
RESET_GPIO_NUM; config.xclk_freq_hz =
20000000;       config.pixel_format      =
PIXFORMAT_JPEG;  if  (psramFound())  {
config.frame_size  =  FRAMESIZE_UXGA;
// Max resolution config.jpeg_quality = 10; //
Image compression config.fb_count = 2;
} else {
  config.frame_size = FRAMESIZE_SVGA;
  config.jpeg_quality = 12; config.fb_count
  = 1;
}
// Initialize Camera
esp_err_t err = esp_camera_init(&config); if (err
!= ESP_OK) {
  Serial.printf("Camera init failed with error 0x%x", err); return;
}
// Create Web Server
httpd_config_t                httpd_config            =
HTTPD_DEFAULT_CONFIG();   httpd_handle_t   server   =
NULL;   httpd_start(&server,   &httpd_config);   httpd_uri_t
uri_stream = {
  .uri = "/",
```

```
        .method = HTTP_GET,

        .handler = streamHandler,

        .user_ctx = NULL
};
httpd_register_uri_handler(server, &uri_stream);

    Serial.println("Camera Web Server Started");

}
```

How It Works ?

1. Wi-Fi Initialization:
   a. The ESP32-CAM creates a Wi-Fi hotspot (Access Point mode) with SSID ESP32-CAM and password 12345678.
   b. Alternatively, you can configure it to connect to an existing Wi-Fi network (Station Mode).
2. Web Server Hosting:
   a. A local web server is created on port 80, hosting a page for real-time video streaming.
   b. The stream can be accessed via a web browser by entering the ESP32-CAM's IP address (displayed on Serial Monitor).
3. Camera Initialization and Video Processing:
   a. The OV2640 camera module is initialized with optimal settings.
   b. The camera captures live frames, compresses them as JPEG images, and sends them via the webserver.
   c. The browser continuously receives and updates the stream, creating a real-time video feed.

How to View Live Streaming ?

- Method 1: Connect Directly (AP Mode)

1. On your phone or computer, connect to the ESP32-CAM Wi-Fi network (SSID: KSP, Password: vivek,1234567890).
2. Open a web browser and enter: http://192.168.4.1
3. The live camera stream will appear.

- Method 2: Connect via Home Wi-Fi (STA Mode)
  1. Modify the `ssid` and `password` variables to match your Wi-Fi network.
  2. Upload the code to the ESP32-CAM and check the Serial Monitor.
  3. Find the ESP32-CAM's assigned IP address and enter it in a web browser: http://<ESP32-CAM-IP>
  4. The live video stream will be displayed.

Customization and Enhancements

- Modify Resolution
  - Change config.frame_size = FRAMESIZE_UXGA; for higher quality or FRAMESIZE_VGA; for faster streaming.
- Add Image Capture Button
  - Modify the web interface to save frames on button click.
- Enable Night Vision
  - Attach IR LEDs for low-light operation.
  - Integrate with STM32
  - Use Bluetooth or UART to trigger image capture based on detection events.

Conclusion

This code enables local video streaming from the ESP32-CAM using a self-hosted web server. The live feed can be accessed without the internet, making it ideal for field surveillance in landmine detection. Future improvements can include cloud integration, AI-based image recognition, and IoT-based data logging.

Appendix-- I

```
void handleCommand(char command)

{

 switch (command)

 {

 case 'F': // Move Forward

 digitalWrite(IN1, HIGH);

 digitalWrite(IN2, LOW);

 digitalWrite(IN3, HIGH);

 digitalWrite(IN4, LOW);

 break; case 'B': // Move

 Backward digitalWrite(IN1,

 LOW); digitalWrite(IN2,

 HIGH); digitalWrite(IN3,

 LOW); digitalWrite(IN4,

 HIGH); break; case 'R': // Turn

 right with delay

 digitalWrite(IN1, LOW);
```

```
digitalWrite(IN2,          HIGH);

digitalWrite(IN3,          HIGH);

digitalWrite(IN4, LOW);

 delay(500); // Adjust delay as needed for turning angle

 // forward after turning

 digitalWrite(IN1, HIGH);

 digitalWrite(IN2, LOW);

 digitalWrite(IN3, HIGH);

 digitalWrite(IN4, LOW);

 break;

case 'L': // Turn left with delay

 digitalWrite(IN1,     HIGH);

 digitalWrite(IN2,      LOW);

 digitalWrite(IN3,      LOW);

 digitalWrite(IN4,     HIGH);

 delay(500);  //  Adjust  delay

 as needed for turning angle
```

```
  // forward after turning
 digitalWrite(IN1, HIGH);
 digitalWrite(IN2, LOW);
 digitalWrite(IN3, HIGH);
 digitalWrite(IN4, LOW); break;
 case 'S': // Stop digitalWrite(IN1,
 LOW); digitalWrite(IN2, LOW);
 digitalWrite(IN3, LOW);
 digitalWrite(IN4, LOW); break;
 case 'G': // Send GPS
 Coordinates sendGPSData();
 break; default:
  Serial1.println("Invalid      Command");
  break;
 }
}
```