A Novel Approach to Metal Detection: Robotic Vehicle with Live Video Feed and Location Tracking

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This paper aims to develop a semi-autonomous robot that is capable of detecting metals in its path. The project presents a fully functional robot that moves on wheels with a conveyor belt mechanism demonstrating a dynamic mobility system. It uses the Wi-Fi module of ESP-32 as a primary microcontroller for its work ensuring efficient and wireless operation. The robot operates in two modes: manual control through a Bluetooth application and autonomous mode for automatic metal detection and movement. The metal detector rover is a robot that can detect the metal in a certain region, and make an alert buzzer sound to show the presence of metal. Beyond metal detection, this innovative design incorporates additional functionalities such as the real-time live location of the robot, and a live stream (visual perspective of the robot's environment) of the surroundings via a CAM (Camera) module accessible on web pages. This project provided one with significant insight into GPS location tracking, ESP-32 microcontroller utilization, CAM module integration, and metal detecting.

Keywords: ESP32, ESP32 CAM, GPS, Metal Detector, wi-fi.

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1. Introduction

The robotic metal detector is a basic principle of robotics to detect metals in its path and it is controlled by an application. This project is designed to develop a mobile robot that can sense metals ahead of it on its path. The design of the robotic metal detector involved the application of different microcontrollers to provide a more effective form of metal detection. Normally, the metal detectors only detect the metal in its path, it doesn't have location tracking feature, Image feature. It just sends an alarm signal to the user or to the system. This metal detector has features like GPS tracking and CAM module which makes it extraordinary and effective. Metal detectors play a crucial role in various industries, such as food processing, pharmaceuticals, textiles, and mining, to ensure product quality and safety. They help identify and remove metal impurities from raw materials, finished goods, and packaging, ensuring safety and compliance with regulatory standards. In construction and demolition sites, metal detectors help avoid accidents, injuries, and damage to subsurface infrastructure. In law enforcement and forensics, metal detectors are used to locate weapons and gather crucial data from crime scenes, such as bullets.

2. Literature Survey

Vinayak Gupta et al. [1] developed a landmine detection robot that utilizes IoT and GPS technology to detect landmines in war-torn areas. The robot is operated remotely and can traverse mine-ridden areas without putting soldiers' lives at risk. The GPS technology enables the robot to obtain latitude and longitude coordinates of the identified position, and the locations of detected landmines can be accessed through mobile phones using GPRS and SMS. The use of mobile phones for robotic control offers the benefit of robust control, allowing fora working range as extensive as the coverage area provided by the service provider. However, the wireless-controlled robots typically employ RF circuits, which have limitations such as restricted working range, limited frequency range, and limited control capabilities.

Ayushi Pandey et al. [2] present the design of an economically designed Unmanned Ground Vehicle (UGV) for the demining process. The UGV is equipped with an IR sensor and metal detector and controlled using an Arduino microcontroller. The UGV is built on a six- wheel drive controlled by two motor drivers, which is equipped with an IR sensor to detect the heat signature of buried landmines and a metal detector to detect metallic landmines. The GPS location of the landmine is sent directly to a mobile device using a GSM Module. The UGV is controlled using Bluetooth remotely. The paper concludes that the UGV has potential applications in detecting and removing landmines safely, minimizing the risk of human casualties. Future work could involve improving the system's accuracy and efficiency to make it a more effective tool for landmine detection and removal. However, the paper does not mention any limitations of the proposed design.

AndrezejFraczek [3] presents the design and implementation of a mobile manipulator system for industrial applications. The system consists of a mobile platform with a caterpillar track and a manipulator arm with six degrees of freedom. The manipulator arm was designed using the Denavit-Hartenberg notation and the lengths of the manipulator members were selected using a method developed by Siciliano, Sciavicco, Villani, and Oriolo. The system was tested by performing pick- and-place tasks on different objects and the results were analysed. However, the system has some limitations, including the need for accurate calibration of the locator and the impact of the caterpillar track on the movement of the mobile platform.

Abilash and J. Paul Chandra Kumar [4] propose a prototype model of a land-mine detection robot (LDR) that can be remotely operated using Wi-Fi technology. The robot is designed to detect and diffuse landmines, which can save civilian lives and avoid human casualties. The robot is equipped with special range sensors to avoid obstacles and a metal detector to sense landmines. The robot is controlled by an Arduino microcontroller and is interfaced with a PC using a ZigBee device.

Waqar Farooq et al. [5] propose a wirelessly controlled robot that can detect buried mines in defense fields to avoid human casualties. The robot is equipped with special wheels and range sensors to move in all directions and avoid obstacles. A wireless camera is added to the robot to capture and broadcast its location. The robot is controlled by a microcontroller, and the paper focuses on the safety of humans and the robot. However, the paper does not provide information on the accuracy, cost, durability, scalability, and impact of weather conditions on the robot's performance.

Muhammad Zubair and Mohammad Ahmad Choudhry [6] present a prototype model of a low- cost landmine detecting robot capable of path planning. The robot uses a metal detector sensor and image processing techniques to detect landmines and accurately map the scanned and leftover areas. The system includes a graphical user interface for remote control of the robot in auto, semi-auto, and manual modes. The values of proportional, integral, and derivative gains are stored in EEPROM of the microcontroller, and wireless serial modules are used for communication between the robot and computer. However, the paper does not mention any field testing or evaluation of the robot's performance in real-world scenarios.

HirziMohdIshak et al. [7] present a monitoring system that uses GPS for an autonomous metal detector robot. The system controls the GPS receiver to start data collection, filters and processes the data, and displays the results on a monitor using GIS. The location and speed of the robot were monitored and reported to a base station. The mapping program was implemented using visual programming languages integrated with Google Earth. The system was able to detect the position of the mobile robot, but the mapping area needs to be larger for wider usage.

EzeoforChukwunazo et al. [8] present the design of a robotic vehicle capable of providing real-time video surveillance for military and wildlife research operation applications. The vehicle is made up of radio frequency-based remote control, a PWM-enabled motor driver IC for efficient mobility, an OV2460 camera, and ESP32-CAM with Wi-Fi enabled for video streaming without an internet connection. The ESP32-CAM also serves as a web server which can be accessed by any device's browser connected via Hotspot setup. The robotic vehicle was tested successfully and communicates effectively with the remote control unit on the average of 0.5km distance.

Vachan B D et al. [9] proposes a wireless robot system for landmine detection using metal detectors and buzzer alarms. The robot can be controlled wirelessly and can detect the presence of any silver object (bomb) through the buzzer alarm. The system uses a 433MHz transmitter and receiver for communication. The robot can be further enhanced by adding components such as a remote camera for external monitoring. However, the paper does not provide any experimental results or analysis of the system's performance.

Seiji Masunaga and KenzoNonami [10] discuss the development of a Controlled Metal Detector (CMD) for landmine detection using a robot. The CMD controls the gap and attitude of the sensor head to improve detection performance. The trajectories of the sensor head are generated using depth information from a 3- D stereo vision camera. Experimental studies demonstrate the effectiveness of the CMD in improving landmine detection performance. However, the experiment assumes a specific range of detection area and parameters, and the effectiveness of the CMD may vary in different environments.

Ian T. McMichael et al. [11] proposes the use of Electromagnetic band-gap (EBG) antennas for handheld sensing applications, such as ground- penetrating radar (GPR) for landmine detection. The proposed EBG antenna is composed of very thin metal to allow co-locating with a metal detector without causing a significant self- response in the metal detector. The paper discusses the manufacturing methods and presents GPR measurements from the thin-metal EBG antennas. The metal detector response from a thin metal sheet is also discussed, and measurements of the EBG ground planes are shown using a laboratory wideband electromagnetic induction system. The proposed

EBG antenna shows promising results, but further research is needed to validate its effectiveness in real-world scenarios.

3. Method

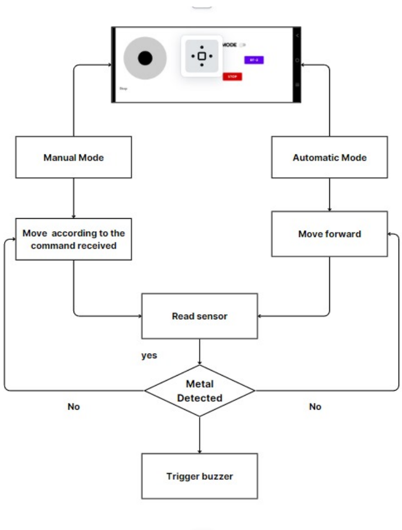

Fig. 1. Flowchart of Controlled Metal Detection Process

This metal detector robot uses ESP32, GPS, CAM module and metal detector sensor. As we can see in the Fig.(1), the robot can be controlled through Bluetooth Application. The direction in which the robot moves (Forward, Backward, Right, Left or Stop) can be controlled through this based application. The project showcases a fully working robot that uses a conveyor belt mechanism to move about on wheels in order to demonstrate a dynamic mobility system. If there is metal in the path, the buzzer will turn on by generating an electromagnetic field, the detector can identify conductive metal objects by detecting the small electric current induced in the metal when it interacts with the field and give an alert sound. The signal pin is connected to the GPIO pin of ESP32 microcontroller. The ESP32 microcontroller module supports Bluetooth connectivity, allowing it to connect to wireless networks and communicate with applications. The ESP32 provides multiple modes of operation for Wi-Fi connectivity, offering flexibility and various features for different application requirements. Bluetooth mode: The Bluetooth mode of the ESP32 can be controlled and configured through software using the ESP-IDF (EspressifIoT Development Framework) or Arduino libraries(Arduino IDE), depending on the development environment you are using. As soon as the metal is detected, we can print the result on the serial monitor. Serial monitor prints metal detected or not on the screen. The GPS module is used for location tracking it connects with the satellite and the exact location of the metal detected can be seen on the web page created on localhost. This GPS module gives longitude and latitude values of the location. The CAM module attached to vehicle streams has a live perspective of the surroundings.

4. Results

Our meticulously created and implemented metal detector finds and locates metallic items with remarkable accuracy. The table below shows comparison of several metals based on their electrical conductivity (measured in MS/m) and electromagnetic intensity (low, medium, or high). Lead and zinc have low electrical conductivity, but silver, copper, and gold have high conductivity. Gold, silver, copper, and aluminum have high magnetic intensities, while iron and bronze have medium intensities.

Table 1. Comparative Metal Attributes

Metal	Electrical Conductivity (MS/m)	Electromagnetic Intensity (Relative)
Iron	10.0	Medium
Gold	43.0	High
Silver	63.0	High
Copper	58.0	High
Aluminum	37.7	High
Gold	43.0	High
Bronze	7.8	Medium
Lead	4.6	Low
Zinc	16.6	Low

The tool detects hidden or buried metals by using the electromagnetic induction principle in an efficient manner. The search coil creates an oscillating electromagnetic field as it moves across the ground, interacting with any nearby conductive metal items. Because of this contact, the metal experiences a little electric current, which creates a secondary magnetic field. This secondary magnetic field is picked up by the metal detector's reception coil, and the control unit examines the signal's properties and intensity to identify the kind of metal and how far below the surface it lies.

The user is informed about the position and identification of the identified metal using both visual and audio signals, including an audible tone and a digital display. The GPS module locates the metal detecting site's geographic coordinates with precision by establishing a smooth link with satellites. For ensuing recovery operations, this real-time position data is quite helpful. Furthermore, the CAM module allows for remote monitoring and navigation by offering a continuous visual stream of the robot's actions.

5. Discussion

The metal detector shows how robotics is a powerful tool to build tools that can be used for specific tasks which humans can't do easily. The metal detector robot helps improve safety in various locations and can locate items during emergencies. It has the ability to navigate through challenging terrains where humans may struggle to move easily. During the project, we encountered difficult challenges. However, through consistent effort and learning, we successfully resolved these issues. In addition to its standard functionality, robot has extra features like live GPS tracking, streaming videos in real-time, and the ability to work in two different ways using Wi-Fi and Bluetooth connections. These characteristics not only facilitate the process of locating metals but also makes the robot useful for things like keeping places safe and working in industries. By combining old-fashioned metal detection methods with new technologies like ESP32 microcontrollers and wireless communication an innovative solution can be found which could change how metal detection systems work in different areas.

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