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Land Mine Detection Robot

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Abstract: Land mine detection is vital throughout warfare to deploy armed vehicles with detection technology within the enemy territory. The increasing threats of terrorism have necessitated the development of advanced technologies for the timely detection of explosive devices. This study introduces a novel approach to landmine detection using wheeled mobile robots equipped with a sensor integration of metal detectors, IR sensors and ESP32 micro controller. The proposed system leverages the sensitivity of IR sensors to detect a temperature spike to enhance the efficiency and safety of landmine detection operations. The mine detection system comprises a lightweight metal detector mounted on a custom-designed mobile robot chassis. The metal detector is configured to identify metallic components commonly found in explosive devices. The mobile robot is equipped with autonomous navigation capabilities and, enabling it to cover large areas rapidly and transmit data to a ground control station. Moreover, an IR sensor is also used to detect heat spikes which are normally emitted by the buried mines.

Keywords: Metal Detector, IR, ESP32, Sensor Integration.

I. INTRODUCTION

In an era marked by evolving security threats, the need for advanced technologies to counteract potential dangers, particularly explosive devices, is paramount. Traditional methods of mine detection often face limitations in terms of coverage, efficiency, and accuracy. This project explores a groundbreaking approach by integrating autonomous wheeled vehicles with metal detectors and IR sensors to create a highly mobile and effective system for mine detection. The primary objective of the landmine detection robot is to enhance the safety and ac- curacy of detection operations. Traditional landmine detection techniques are labour-intensive, timeconsuming, and fraught with danger. By integrating robotic systems into detection processes, it is possible to mitigate these risks and improve the efficiency of landmine identification. The robot utilizes a metal detector to identify metallic components within landmines, while the IR sensor aids in detecting heat signatures and distinguishing landmines from other metal objects that may be present in the environment.

The dual-sensor approach significantly improves the accuracy and reliability of the detection system. The metal detector serves as the primary sensor, detecting the presence of metal typically found in landmines. However, given the prevalence of various metallic debris in mine-affected areas, the inclusion of an IR sensor enhances the system's capability to differentiate landmines from innocuous metal objects. The IR sensor detects thermal variations on the surface, indicating the presence of objects with distinct thermal properties, such as landmines.

In conclusion, the development of a landmine detection robot utilizing a metal detector and an IR sensor offers a promising solution to the global challenge of landmine identification. By leveraging advanced robotics and sensor technologies, this project aims to contribute to safer, faster, and more effective landmine detection operations, ultimately aiding in the restoration of landmine-affected areas and improving the safety and quality of life for communities in post conflict regions.

The main contributions of this paper are:

- Developing an autonomous bomb detection unit using a metal sensing module, IR sensing module and ESP 32 micro controller.
- Control, simulate and implement robot mobility.
- Integrating the metal sensing module, IR sensing module and ESP32 with the autonomous robot.

II. LITERATURE SURVEY

The demand for military robots has skyrocketed in the modern era. As a result, capable robots start to develop. A portion of robotic platforms, including remotely operated vehicles, carry out dangerous tasks in both military and civilian settings. The creation and use of such robots could replace people in a number of hazardous tasks. The human operator receives the information about the environment that is being watched. Through teleoperation, the human operator can operate the machine. The biggest threat to law enforcement and military personnel is the possession of explosives. Robots and tactics

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for disposing of bombs have garnered renewed interest due to recent advancements. Disarming the device with little human interaction is the goal.

One commonly used system uses a metal detector coil for detecting mines and other bombs. This system [1] comprises three primary components: an Arduino microcontroller, a robotic arm, and a water jet cutter. The Arduino microcontroller serves as the system's central processing unit, controlling the robotic arm's movements and coordinating with the metal detector and water jet cutter. The robotic arm, equipped with a metal detector, scans the designated area for potential bombs. Upon detecting a bomb, the system alerts the operator, who then employs the water jet cutter to safely dismantle the device.

Arduino-based Control: The Arduino microcontroller provides precise control of the robotic arm and its integrated sensors, ensuring accuracy and responsiveness during detection and disposal operations.

Metal Detector for Bomb Localization: The metal detector enables early detection of potential bombs by identifying the presence of metallic components, which are common in explosive devices.

Water Jet Cutter for Safe Disposal: The water jet cutter eliminates the risk of detonation by using high-pressure water to safely cut through bomb casings and disrupt internal components.

Radio Frequency Module: An RF module enables the remote control of the robot. It has a frequency range between 400 and 500MHz. This is done by using an encoder in both the transmitter and receiver to convert parallel data to serial format.

It also incorporates a wireless camera. The authors conducted simulated testing to evaluate the system's performance and effectiveness. The results demonstrated that the system successfully detected and disposed of bombs in a controlled environment. The simulated testing allowed for the refinement of the system's design and operation prior to real-world deployment. Apart from the metal detectors, various other technologies are being developed by researchers to better identify the landmines. One such approach includes using the depth information to calculate the exact distance to the mine. For this depth cameras are used. One such depth camera developed for the purpose of bomb detection is the Canesta depth camera [2] created by Canesta Inc. which is mounted on a robot arm. The Canesta functions as an active depth sensor, emitting pulses or flashes of near-infrared laser light akin to a traditional camera flash. It determines the distance to objects by leveraging the properties of light and phase shift, assigning a unique value to each pixel. It can achieve a maximum depth resolution of approximately 5mm within a minimum range of 1.44 meters. The field of view is captured in a 64x64 pixel image. The interface was designed with Java to integrate smoothly into a Java-based robotic framework. It encompasses four primary features:

A. Depth Display: Sometimes, the precise depth measurement is required. This need for precise depth measurement was incorporated to the design. When the operator hovers the mouse cursor over the sensor output display, the depth corresponding to the pixel under the cursor is shown.
B. Distance to the Object: The authors' proposed program automatically adjusts the display to match the distance of the object represented by the selected blob. A pink dot appears at the centre of the blob when the user clicks on it. This dot indicates the blob being tracked, and its colour is chosen for high contrast with other display colours to enhance visibility.
C. Tracking Distance to the Object: This feature extends the distance-to-object functionality. The tracking continues until the user disables it by double-clicking on the sensor output display. Additionally, this method allows the displayed object to expand or contract as the Canesta sensor on the robot moves closer to or farther from the detected object.
D. Distance Cueing: The interface design includes a feature that alerts the operator when objects are too close to the grasper. The operator sets a predefined safe distance for both the grasper and the disrupter, typically a preset value for each robot model. If the pixel under the cursor is within this safety distance, the alert box turns yellow to indicate caution. If the robot moves closer, the alert box turns red. SMEs need to easily switch between the grasper and the disrupter, each having different depth measurement points, known as the zero point or base distance. To facilitate this, the authors added two buttons to the interface: one for the grasper and one for the disrupter. Clicking a button changes the current base distance to the one used for the grasper or the disrupter.

Recent advancements have seen the integration of sophisticated sensors and control systems. For instance, the development of adaptive trajectory tracking by Shojaei et al [3]. has been crucial for improving the precision and reliability of robot movements. A detailed information about the control software and mechanics of the robot has been

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shown [3]. Thin aluminium frames are used for the outer body of the robot. The proposed design is a 4 wheeled robot where DC motors are used to provide movement. On the top a Mini2440 development board, USB mux and a battery are attached. A camera is also used with the robot for visual identification.

A PIC116F877A microprocessor and a Mini2440 development board is used. The software for the PIC16F877A is written in C. It comprises two main sections. The first section continuously listens to the serial port to handle requests from the Mini2440. The second section manages processes like the control of the DC motor group and the step motor. A webcam is used to transmit images via TCP communication, utilizing mjpeg streamer software on the Mini2440. The DC motor functions are executed through UDP communication. A visual operator control interface based on Qt Creator has been developed to enable effective robot movement and the use of other system units. This operator interface software allows for remote control of the robot from the computer. The interface features a video display client, a thread for managing different processes at varying times, and a motor control client (UDP client). The Thread software allows UDP and TCP/IP clients to function independently on the same interface without issues. The mobile robot system developed here [3] can record video and transmit it to a computer. Additionally, the robot can be remotely directed to a target and can fire the AKER weapon if needed. The AK-ER bomb disposal weapon, equipped with an ignition lever, can neutralize suspicious setups by deactivating the electronic detonator.

All the above-mentioned models were mostly four wheeled mobile robots integrated with mine/bomb detection system. The disadvantage with using 4 wheeled mobile robots is that it is difficult for these robots to traverse uneven terrains. This design constraint can be overcome by using a rocker bogie mechanism [4] which can easily move across uneven terrains. A rocker bogie mechanism along with a two way talk feature and hand gesture control of robotic arm is discussed here [4]. The proposed system includes a Wi-Fi camera capable of live streaming and recording both day and night. It can capture a full 360 degrees horizontally and 120 degrees vertically. It also features a two-way talk feature. The mechanical design is based on the mars curiosity rover which was based on rocker-bogie mechanism. The advantage of using this mechanism is that it can easily move on rough and difficult terrains and provides a climbing functionality over some terrains.

This crawler can be operated wirelessly using HC05 Bluetooth module which is used as a receiver and is connected to a Arduino uno board at Rx, Tx, GND, +5V pins which ensures it gives proper instructions via the controller. The controller is usually a mobile phone installed with an application. The model proposed by the authors, is made using UPVC which helps it in giving a skeletal support. The authors achieved a range of 429 feet on its first test run.

The camera is used for surveillance is dangerous areas. It has a FOV of 360 degrees along the horizontal plane of axis and up to120 degrees on the vertical axis. The camera proposed by the authors works on 2.5 GHz bandwidth frequency. Four servo motors having a torque of 9.8-11 kg/cm are used for the movement of the robotic arm. These four motors provide the arm with four degrees of freedom. A flex sensor is used for controlling the arm. MPU 6050 is a threeaxis gyro sensor and with hand movements, it rotates the arm. An Arduino pro mini is used as the decision-making device on the transmitter end and this is further connected to a trans receiver NRF24L01 and acts and generate signals which is being transferred to this transmitter and on the receiving end, it has another trans receiver which receives the signal and passes onto the Arduino. The trans receiver with antenna has a range up to 1Km. A clipper is also used to cut the wires and dispose the bomb. All these papers mostly focus on wheeled mobile robots. Although wheeled mobile robots are the mostly preferred for various applications as they are cheaper compared to their flying counterparts, wheeled mobile robots for landmine detection are more prone to attacks. To counter this am UAV based system for bomb detection [5] can be used. Using the quadcopter type UAV system can reduce the time taken to detect the bombs as UAVs can cover large areas quickly. The authors propose using a quadcopter as the UAV system and the bomb detection is done by using a Geiger Counter Module. This Geiger moule can detect any type of radioactive radiation emitted from the bomb. A GPS module and a GSM module has also been incorporated into the system. Four motors are used for the quadcopter mechanism and the speed of the four motors are different. Motors along one diagonal rotates in one direction and the other two motors along the other diagonal rotates in the opposite direction. The motion control of the quadcopter is achieved by varying the thrust which can be done by varying the speed of the motor. By varying the thrust, we ca also achieve take-off and landing mechanism.

A PID controller is used for the stabilization of the quadcopter. Stabilizing the quadcopter in horizontal position is done by making the velocities and angle to zero. A kk2 board is used in this research paper for quadcopter stabilization. The proportional and integral values need to be tuned properly to stabilize the quadcopter.

The proposed Geiger module can detect any type of radioactive radiation. It is possible to detect alpha, beta, gamma radiation by using the Geiger module. The Geiger module basically works on the principle of ionization. When

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radioactive radiation passes through the tube, it undergoes ionization (splitting into ions). Applying voltage causes positive ions to be attracted to the negative terminal and negative ions to the positive terminal of the battery. This ion movement generates a small current. The Geiger module is connected to an Arduino to measure the intensity of ionization. As radiation levels increase, the analogue voltage levels displayed on the Arduino serial monitor also increase. The authors incorporated the Geiger module into a quadcopter as its payload. If radiation exceeds a predefined threshold, the location is transmitted to the operator's mobile using GPS and GSM modules.

Various control methods are employed for the control of these mine detection robots. The control methods commonly used are RF transmitter receiver control. Another such control strategy is the haptic arm control [6]. The haptic arm system is a wireless, self-contained system worn on the user's arm to control robot motion. The mechanical design proposed for this robot resembles a UGV (Unmanned Ground Vehicle). This system [6] includes a user module consisting of a glove worn by an authorized user, allowing robot control through finger motions. Data generated by finger movements is transmitted via a ZigBee transmitter module. A ZigBee receiver module is installed on the robot module. Additionally, a metal detector is used to identify explosives. A GPRS unit sends information to the controller upon detecting explosives, and the gripper can be manipulated using haptics for robotic defusing operations.

Flex sensors are placed on the four fingers of the authorized user, varying their resistance based on finger flexion. Additionally, various machine learning techniques and algorithms are employed for bomb detection. One such method [7] is the GA based autonomous self-localization and mapping mechanism for bomb disposal robots. This approach simulates the localisation, navigation, and mapping of a vehicle's undercarriage. The robot is equipped with an array of sensors on its top and sides. These sensors are primarily used to detect collisions and scan the undercarriage of vehicles. Additionally, a chemical sensor detects any chemical trails left by bombs. The authors' proposed robot utilizes wheeled locomotion, specifically omni wheels, enabling it to move in multiple directions without rotating. An image processing technique is employed to provide input for vertical sensor feedback simulation.

The proposed approach utilizes a distance sensor mounted on top of the robot to determine its position relative to the edge of the vehicle. Different sensor readings correspond to various positions, guiding the robot's navigation. To avoid collisions with the tires while navigating the perimeter, side sensors are employed, and a distance threshold is set for the distance sensors, effectively creating a virtual boundary between the robot and the tires. A fixed grid size of 2 cm establishes a coordinate system, enabling the robot to perform self-localization during navigation. Perimeter mapping begins by selecting an origin point along the vehicle's perimeter, designated as (0,0). Any movement by the robot within the perimeter coordinates is recorded as a local coordinate, which is then used to construct the local perimeter map.

Undercarriage mapping begins by measuring the gross width of the vehicle, which involves navigating along the sides, front, and back. To ensure accuracy, the robot aligns itself perpendicular to the side of the car before taking measurements. To measure the vehicle's length, the robot positions itself in the centre based on the measured width and moves left and right to obtain the length. With both width and length determined, the robot performs the mapping by navigating in a zigzag pattern. During each vertical pass, sensor readings are collected in an array, resulting in a detailed map of the vehicle's undercarriage. Apart from these detection technologies, many other detection technologies are used by various other engineers. To better understand these, a survey was conducted [8] on all the available landmine technologies. Apart from the already presented metal detector, other detection technologies include ground penetrating radar (GPR), IR and hyper spectral methods, Xray backscatter, acoustic and seismic systems, vapour sensors. The GPR provide the most accurate results as it is one of the most efficient methods for subsoil search. A radar signal is transmitted and its reflected signal is analysed based on dielectric variations caused by reflections from the soil, such as the presence of an object. The image resolution improves with shorter wavelengths; however, shorter wavelengths also enhance soil penetration. The disadvantage of using GPR is that they are expensive compared to others.

Infrared (IR) and hyperspectral methods detect abnormal variations in electromagnetic radiation that are reflected or emitted from the mine surface or the soil immediately above it. The objective is to capture the reflected energy from mined areas, where the reflection differs from the surrounding regions. Thermal sensors are also used to exploit the temperature differences between the soil and the mines, primarily due to day and night thermal fluctuations (Boras et al. 2000). This method is most effective in homogeneous soil. Additionally, laser illumination or high-power microwave radiation can be employed to create these differences. X-ray backscatter (XBT) technology is promising for achieving low false alarm rates and high detection probabilities. This method generates images of objects by passing X-rays through materials and analysing the attenuation (absorption or scattering) that occurs. Since placing an X-ray detector beneath the soil to capture penetrating photons is impractical, these systems use the 'Compton principle' of X-ray scattering. This principle enables the detection of photons as they are scattered by the object, allowing both the emitter and receiver to be positioned on the surface.

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Another ground breaking approach is the use of acoustic and seismic sensors. Acoustic and seismic systems [9] utilize speakers to emit sound waves that induce vibrations in the soil. Sensors then detect reflected waves from both the soil and any buried mines. Detection is enabled by differences in amplitude and frequency. Special sensors capable of operating without direct contact with the surface are used, capturing mechanical distinctions between the soil and mines. These technologies can augment data obtained from EMI sensors. Although these systems usually have a low false alarm rate, they can sometimes mistakenly detect objects like bottles and cans. Regarding vapor sensors, a small amount of explosive material can escape as vapor through fissures and shielding structures in mines. The aim is to identify the presence of explosive vapours. Research in this area primarily follows two approaches: biological and chemical. Chemical methods primarily focus on detecting vapours from explosives like TNT, RDX, and PETN, which can be considered as sources of underground vapor. This vapor can be transported by molecular diffusion and turbulence processes. The objective of this method is to develop sensors that can detect these vapours using electromechanical principles, piezoelectric techniques, or spectroscopic methods. This survey [8] came to the conclusion that rather than using a single sensor approach, a dual or multi sensor approach provide the best results with greater accuracy.

III. METHODOLOGY

A. *Selection of Components*

Choose appropriate components based on the defined requirements. This includes selecting motors, motor controllers, batteries, micro controllers frame, and other necessary hardware.

The various components used for this study are:

- 12V DC geared motor at 60 RPM.
- L293D motor driver for controlling the DC geared motors.
- ESP-32 micro controller.
- HC-sr04 ultrasonic ranging module for obstacle detection.
- LM393 IR sensor to detect heat spikes emitted by buried mines.
- A Neo 6 GPS module to notify the operator the exact coordinates at which the mine is detected.
- RS-071 metal detector module to detect the metallic parts of the buried mines.

B. *Selection of the Mine Detection Model*

Various types of bomb detection technologies are available including the most efficient and advanced Geiger module which are mainly used to detect alpha, beta and gamma waves. The Geiger module operates based on the principle of ionization. When radioactive radiation passes through the tube, it causes ionization (formation of ions). Applying voltage attracts positive ions to the negative terminal and negative ions to the positive terminal of the battery, generating a small current. The Geiger module is connected to an Arduino to measure the intensity of ionization. As radiation levels increase, the analogue voltage levels displayed on the Arduino serial monitor also rise. The authors integrated the Geiger module onto the quadcopter as part of its payload. If radiation exceeds a predefined threshold, the system sends its location to the operator's mobile device using GPS and GSM modules.

Here we are using a metal detector module. This metal detector module can be incorporated with an IR sensor and they work together. If a landmine is present, the metal detector module detects it and gives the information to the ESP32. The ESP32 then processes the information and using an RF transmitter, transmits the information to the user. Thus it can be used for mapping the landmines.

C. *Selection of the Coil*

The coil is designed such that it has a diameter of 2.7cm and has a 'O' shape. The operating frequency of the coil varies between 3KHz to 15KHz. A frequency range of 3-5 KHz is chosen so that it can detect almost all the ferrous materials from which the mines are made of. This frequency range is also suitable for detecting mines of small sizes. The 'O' shape is chosen so that it can cover more area.

The metal detector coil consists of 2 internal sets of coiled wires:

- Transmitter coil (Tx): Generated a magnetic field.
- Receiver coil (Rx): Detects the transmitted field from the metal objects.

The receiver coil senses changes in the re transmitted field, producing a target response.

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Fig. 1 An image of RS-071 metal detector coil

D. *Working of the Coil*

The core of this sensor is its inductive oscillator circuit, which monitors high-frequency current losses in the coil. This circuit is specifically designed to detect metallic objects by sensing changes in high-frequency eddy current losses. With an external tuned circuit, these oscillators are activated. The output signal level is affected by the proximity of a metallic object. The signal output depends on changes in supply current. Regardless of the supply voltage, this current varies as a result of the presence or absence of a nearby metallic object. When a metal object is close to the search coil, the output current increases. Conversely, the current decreases as the object moves away from the search coil.

Figures and tables must be cantered in the column. Graphics must not use stipple fill patterns because they may not be reproduced properly. Please use only SOLID FILL colours which contrast well both on screen and on a black-and-white hardcopy, as shown in Fig. 1.

Figure Captions

Figures must be numbered using Arabic numerals. Figure captions must be in 10 pt Regular font. Captions of a single line must be cantered whereas multi-line captions must be justified. Captions with figure numbers must be placed after their associated figures, as shown in Fig.

E. *Working of the Proposed Model*

The ESP32 micro controller is chosen as the central processing unit. It receives information from all the sensors, process the information based on algorithms. A ESP8266 is used to gives commands to 12V geared motor for the movement of the robot via the L293D motor driver. The metal detector coil works on the principle of electromagnetic induction. It detects the land mine based on the disturbance received on the detector coil. This disturbance is caused by the eddy currents in the metal object i.e. the landmine.

An IR sensing module is used to check for changes in thermal signature. A buried land mine will probably be at a higher temperature than the environment temperature as it is constantly soaking up all the heat radiation from the soil. The IR sensor is set at environment temperature such that a spike in environment temperature of about 10-12 percent will trigger it. These data from the metal detector module and the IR sensor is used by the ESP32 micro controller to analyse whether a land mine is present or not.

If a land mine is detected an LED cue light positioned at the base of the robot starts to blink indicating that a land mine is present. A GPS module is used which constantly updates the coordinates of the robot.

As soon as a land mine is detected the ESP32 send the coordinates of the location where the land mine is found to the operator via a telegram bot. Thus, the operator can identify at which all locations land mines are present. As for the movement of the robot, an IR sensor is fixed near the left wheel to detect the number of rotations of the wheel. The program is written such that after 10 rotations, the robot turns left, then moves 3 rotations forward, then again moves 10 rotations forward, and so on. Using this movement strategy the robot can cover the whole area of the mine field.

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Fig. 2 shows the circuit diagram of the developed model. Two micro controllers, an ESP 32 and an ESP8266 are used. The ESP8266 is used to control the DC geared motors using the L293d motor driver and the ESP32 is used to process the signals from the mine detector coil, GPS sensor, IR sensor and an ultrasonic sensor.

Fig. 3 shows the block diagram of the developed model. A power module is used as the power source for the ESP 32 micro controller. For this a 12V supply is used. 12V rechargeable batteries are used or this. Another 5V supply is used as the power source for the metal detector coil.

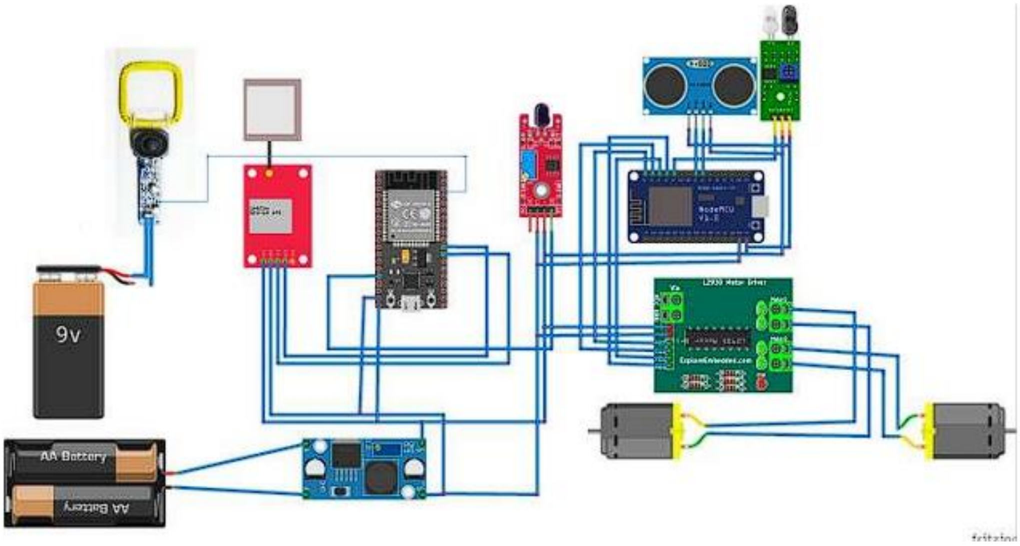

Fig. 2 Circuit diagram of the developed model.

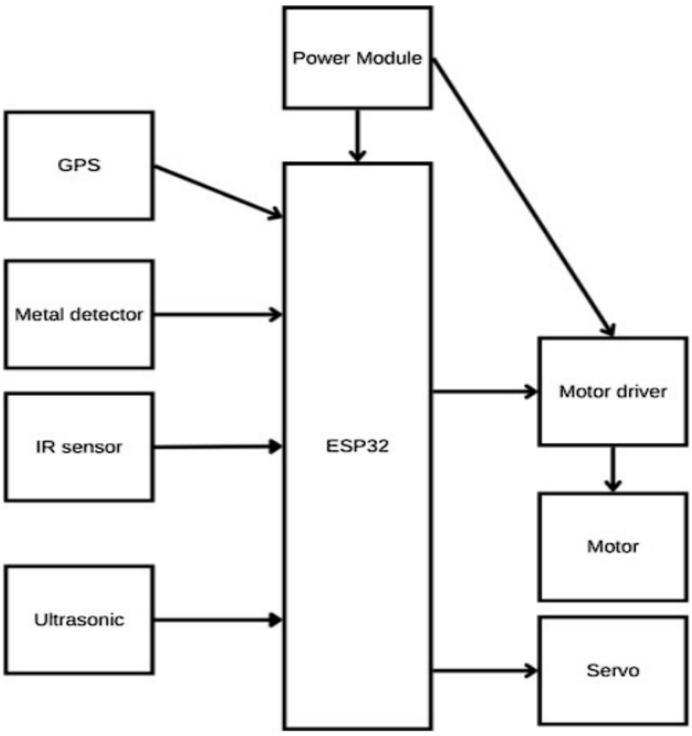

Fig. 3 Block diagram of the developed model.

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IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. *Mine Detection Test Results*

1. A depth analysis was conducted to analyse the maximum depth up to which the coil can detected buried metals designated as land mines. This showed that the coil was able to successfully detect mines up to a depth of 15cm. Beyond that the coil produces an output zero meaning no metal has been detected. **Table 1** shows the results from depth analysis. It shows the maximum depth up to which the coil could detect buried mines.

   Fig 4 shows the depth analysis plot of the coil. This was done to find out the maximum depth at which the coil can detect mines effortlessly. The maximum depth was found out to be 15cm and this is a desired range as most anti-personnel mines are buried at a depth of about 10cm.

TABLE 1 DEPTH V/S OUTPUT

Sl.No.	Depth (in cm)	Output (binary)
1.	3	1
2.	5	1
3.	7	1
4.	9	1
5.	10	1
6	11	1
7.	12	1
8.	13	1
9.	15	1
10	16	0

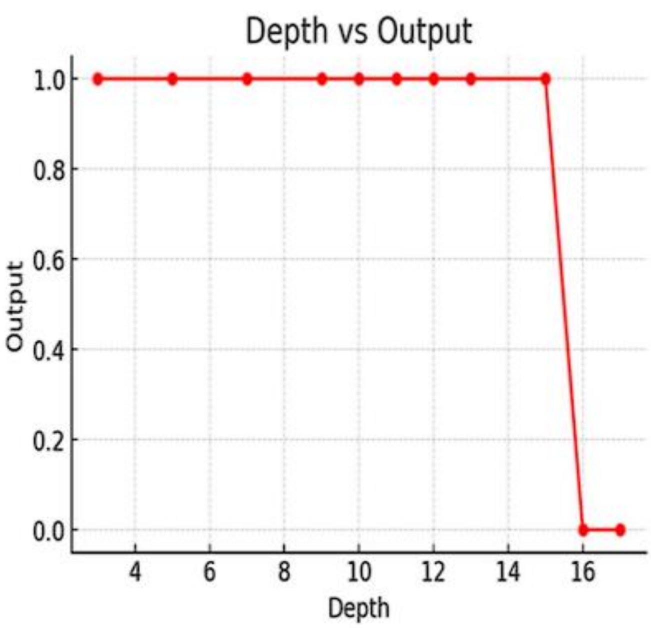

Fig. 4 Depth v/s output graph plotted using the data from Table1

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2. An analysis was conducted to study about the frequencies at which different metals are detected by the mine detector coil. This analysis was done so that we can find out whether metals like aluminium and steel can be detected by the coil, as some mines now use a combination of steel and aluminium. **Table2** shows the frequencies at which different metals are detected by the coil.

Fig. 5 shows the graphical representation of the frequency at which different metals are detected by the coil. This plot shows us that the coil can detect metals in the frequency range up to 15KHz. This is important as we can use the plot to understand if the coil could be used to detect materials like steel and aluminium which are sometimes used in landmines.

TABLE 2 FREQUENCY V/S METALS SHOWS THE VARIOUS FREQUENCIES AT WHICH DIFFERENT METALS ARE DETECTED BY THE COIL

Sl. No.	Tested Metal	Frequency at which it is detected by the coil (in KHz)
1.	Brass	3
2.	Silver Plate	4
3.	Aluminum	5
4.	Nickel	7
5.	Steel	10
6.	Iron	12
7.	Silver Earrings	12

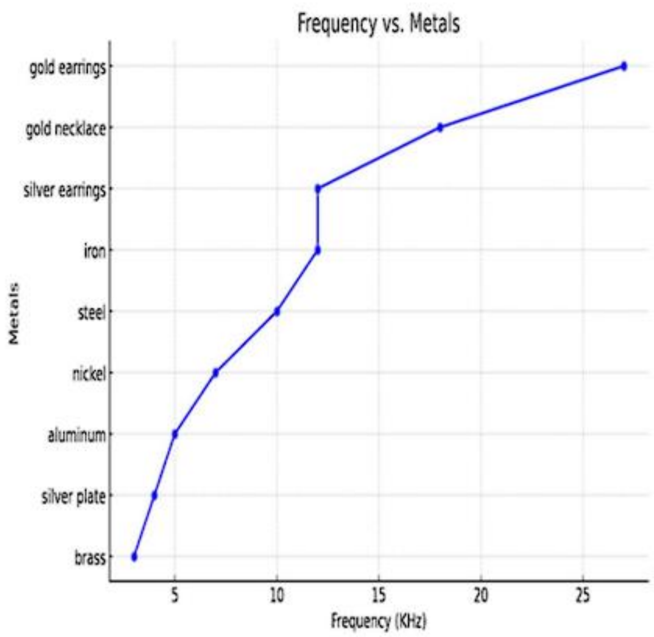

Fig. 5 Frequency v/s output graph plotted using the data from the Table 2.

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3. A test was carried out by placing many metal and plastic objects side by side and assigning some of them as land mines, and the number of false detections by the metal detector alone and the number of false detections by the metal detector plus IR sensor were determined. The resulting graph was plotted. Table 3 compares the number of false detections using a metal detector and a sensor integration of metal detector and IR sensor.

Fig. 6 compares the number of false detections with a metal detector only to those with both a metal detector and an IR sensor. It was found that the number of false detections can be brought down to almost zero when a sensor integration of metal detector and IR is used.

TABLE 3 COMPARES THE NUMBER OF FALSE DETECTIONS USING A METAL DETECTOR AND A SENSOR INTEGRATION OF METAL DETECTOR AND AN IR SENSOR.

Distance travelled by the robot	If mine detected	No: of false detections with metal detector only	No: of false detections with metal detector and IR sensor	Total no: of mines	Total number of objects
3 M	Yes	3	0	2	5
5 M	Yes	2	0	1	3
5 M	Yes	4	0	3	7
7 M	Yes	4	0	3	5
8 M	Yes	2	0	1	4

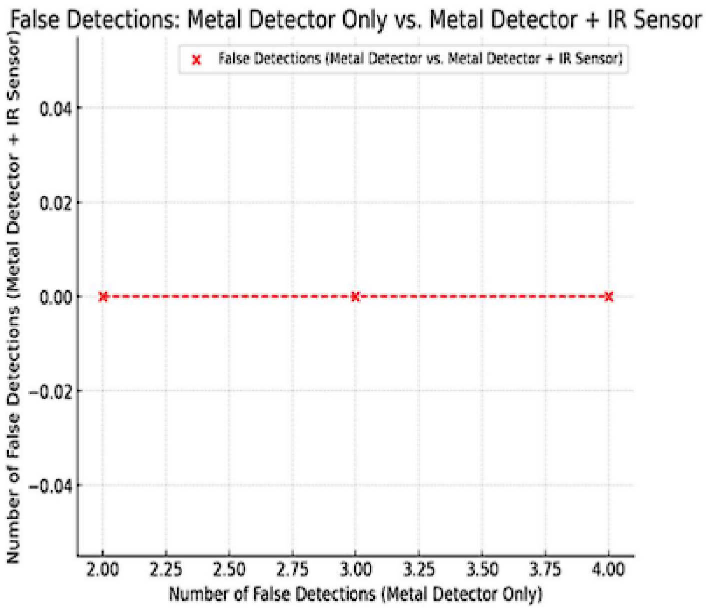

Fig. 6 Comparison of the number of false detections with a metal detector only to those with both a metal detector and an IR sensor.

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Fig. 7 is a graph showing the relationship between the total number of objects and the number of false detections with a metal detector. This shows that if other metals are present in the vicinity of a robot using metal detector only, it might produce false results by considering the scrap metals as land mines too.

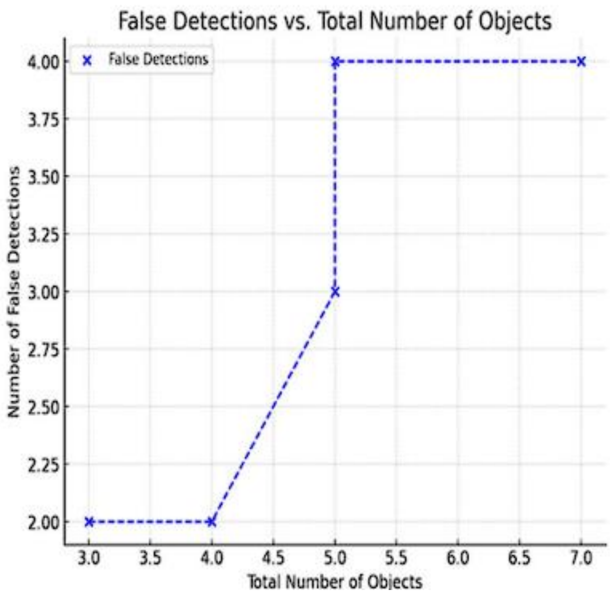

Fig. 7 Graph showing the relationship between the total number of objects and the number of false detections with a metal detector.

Similarly, Fig. 8 shows the relationship between the total number of objects and the number of false detection when using both a metal detector and an IR sensor. From these results, we can come to the conclusion that a dual sensor approach is better compared to using a metal detector only.

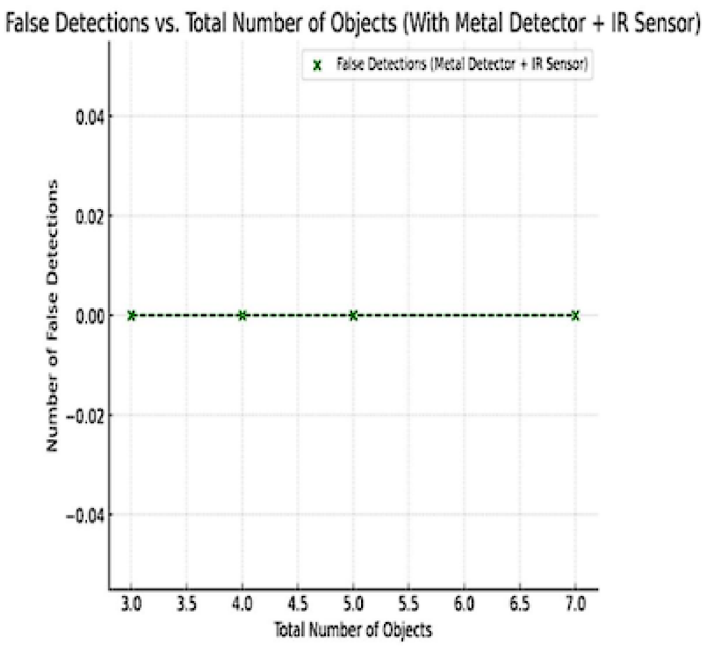

Fig. 8 Graph showing the relationship between the total number of objects and the number of false detection when using both a metal detector and an IR sensor.

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V. CONCLUSION

The development and implementation of the landmine detection robot, integrating both a metal detector and an IR sensor, represents a significant advancement in the field of autonomous robotic solutions for hazardous area detection. The primary objective of this project was to create a reliable, efficient, and autonomous system capable of identifying landmines in a designated area with minimal human intervention.

The integration of a metal detector and an IR sensor proved to be a highly effective solution for landmine detection. The metal detector efficiently identified the metallic components of landmines, while the IR sensor detected heat spikes emitted by buried mines. This dual-sensor approach significantly increased the accuracy and reliability of the detection process.

Tests were conducted to determine the efficiency and accuracy of the robot and it was found that using a dual sensor approach increased the detection accuracy by about 20-25%. Depth analysis was conducted to determine the maximum depth up to which the robot can detect metals. Apart from this, another test was conducted to determine the frequencies at which different metals are detected by the coil.

Contributions include:

1. Designed a mine detection system by integrating a metal detector coil and an IR sensor. The developed system proved to be more accurate than a single sensor system.

2. Developed an autonomous mobile robot.

3. Integration of the autonomous mobile robot with the developed mine detection system.

4. Evaluated the maximum depth up to which the robot could detect mines.

5. Analysed the different metals the mine detector coil could detect.

VI. FUTURE SCOPE

The future scope of this research includes implementing a new mechanical design. The design can be modified into a drone type robot so that it can scan large areas quickly. Also, the drone type robots are less prone to attacks.

Moreover, a Ground Penetrating Radar (GPR) can be used instead of the metal detector and IR sensing module for accurate results. Apart from this, a dual or triple sensor integration can be used for more results.

REFERENCES

[1]. D. S. Navare, Y. R. Kapde, S. Maurya, D. B. Pardeshi and P. William, "Robotic Bomb Detection and Disposal: Application using Arduino", *7th International Conference on Communication and Electronics Systems (ICCES*), Coimbatore, India, pp. 479-483, 2022.

[2]. B. Day, C. Bethel, R. Murphy and J. Burke, "A Depth Sensing Display for Bomb Disposal Robots", *2008 IEEE International Workshop on Safety, Security and Rescue Robotics*, Sendai, Japan, pp. 146-151, 2008.

[3]. A. Unluturk and O. Aydogdu, "Design and implementation of a mobile robot used in bomb research and setup disposal", *Proceedings of the International Conference on Electronics, Computers and Artificial Intelligence - ECAI-2013*, Pitesti, Romania, pp. 1-5, 2013.

[4]. Gupta, Shubham Sen, "Arduino based Surveillance and Bomb Diffusion Robot with Rocker Bogie Mechanism and Two-way Talk Feature using Hand Gesture control Robotic ARM", *International Research Journal of Engineering and Technology (IRJET),* pp. 7-12, 2020.

[5]. C. Manoj, N. SaiTeja, R. A. Kumar, M. J. P. Priyadarsini, K. Murugesan and S. R. Inabathini, "Unmanned aerial vehicle-based bomb detection", *2016 International Conference on Advances in Computing, Communications and Informatics (ICACCI),* Jaipur, India, pp. 2385- 2389, 2016.

[6]. S. Thomas and A. Devi, "Design and implementation of unmanned ground vehicle (UGV) for surveillance and bomb detection using haptic arm technology", *2017 International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT),* Coimbatore, India, pp. 1-5, 2017.

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DOI: 10.17148/IJARCCE.2024.13707

[7]. M. F. Hamza, "GA Based Autonomous Self Localization and Mapping for Bomb Disposal Robot", *2023 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS),* Shah Alam, Malaysia, pp. 247-252, 2023.

[8]. Ismail, Ahmed, Mohammed Elmogy, and Hazem ElBakry. "Landmines detection using autonomous robots: A survey", *International Journal of Emerging Trends & Technology in Computer Science (IJETTCS)*, pp. 184-187, 2014.

[9]. Robledo, L, Carrasco. M, & Mery. D, "A survey of land mine detection technology", *International Journal of Remote Sensing, 30(9),* pp. 2399-2410, 2009.

[10]. . Jaradat, Mohammad A., Muath N. BaniSalim, and Fahed H. Awad. "Autonomous navigation robot for landmine detection applications", *2012 8th International Symposium on Mechatronics and its Applications IEEE,* pp. 1-5, 2012.

[11]. Keerthana, S., A. R. Vellaiyan, and M. Rajamohan, "Bomb detection and disposal robot: Aid for risky Military Fields", *International Journal of Engineering and Advanced Technology (IJEAT), 8(6)*, pp. 602-605, 2019.

[12]. Vachan, B., S. Deepthi, B. Geetha, and L. Srinivasan, "Landmine Detection using Wireless Robot", *International Research Journal of Engineering and Technology, 4(7),* pp. 641-648, 2020.

[13]. Satpute, Mayuresh, Shubham Haridas, Rahul Sutar, and Akash Vatane, "Armed Robot for Bomb, Smoke, Temperature Detection", *International Journal of Mechanical and Production Engineering Research and Development*, pp. 123-130, 2020.

[14]. Awad, Magdy Naeem, Moamen Mohamed, and Naguib Saleh, "Autonomous Landmine Detection Robot Using SLAM navigation Algorithm", *Journal of International Society for Science and Engineering*, pp. 81-91, 2022.

[15]. Hameed, Ibrahim A, "Motion planning for autonomous landmine detection and clearance robots", *2016 International Workshop on Recent Advances in Robotics and Sensor Technology for Humanitarian Demining and Counter-IEDs (RST),* pp. 1-5, 2016.

[16]. Sekhar, T. Chandra, and S. Durga Prasad, "War Field Spy Robot with Ultrasonic Metal Detection and Bomb Diffusion System", *International Journal for Science and Advance Research in Technology*, pp. 123-126, 2018.

[17]. Mardiyanto, Ronny, Muhammad Qomaruzzaman, and Heri Suryoatmojo, "Development of remotely operated bomb disposal robot equipped with object weight and poses estimations", *Journal of Theoretical & Applied Information Technology*, pp. 45-56, 2017.

[18]. Prakash, Prithvi, Sandesh Fernandes, and Syed Rahul, "Real time speech—Interactive bomb disposal robot: With face and object recognition*", 2017 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT)*, pp. 1-12, 2017.

[19]. Paik, Joonki, Cheolha P. Lee, and Mongi A. Abidi, "Image processing based mine detection techniques: A review", *Subsurface Sensing Technologies and Applications 3*, pp. 153-202, 2002.

[20]. Bruschini, Claudio, Bertrand Gros, Fred´ eric Guerne, Pierre-Yves Piece, and Olivier Carmona, "Ground penetrating radar and imaging metal detector for antipersonnel mine detection", *Journal of Applied Geophysics 40*, pp. 59-71, 2008.

[21]. Xiang, Ning, and James M. Sabatier, "Land mine detection measurements using acoustic-to-seismic coupling", *Proc. SPIE 4038, Detection and remediation technologies for mines and Mine like targets*, pp. 645-655, 2000.

[22]. Aoyama, Hajime, Kazuyoshi Ishikawa, Junya Seki, Mitsuo Okamura, Saori Ishimura, and Yuichi Satsumi, "Development of mine detection robot system", *International Journal of Advanced Robotic Systems, 4(2)*, pp. 123-129, 2007.

