BOMB DETECTION AND DIFFUSION ROBOT WITH LIVE ALERTS AND VIDEO STREAMING

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ABSTRACT: Terrorist attacks using bomb have caused many deaths and injuries, creating fear worldwide. Many victims suffer before bomb squads can help, and bomb squad face great danger during their work. These attacks often happen in crowded places, putting civilians and responders at risk. Responding to bomb threats is tough because it requires quick detection and fast communication to keep people safe. The unpredictable nature of bombs increases the danger for those trying to defuse them. This situation shows the urgent need for a system that can quickly detect bomb threats, send real-time alerts, and reduce risks to humans.

This project is designed to safely find and handle bombs using remote control. It uses an ESP32-CAM for streaming live video and controlling the robot, while the ESP32 helps detect explosives and manage the safety procedures for dealing with them. This way, authorities can get real-time updates and control critical operations in the diffusion process.

The robot scans the area using metal detectors, gas sensor and electromagnetic sensor to find bombs. When a bomb is detected, the system automatically sends an alert to notify the authorities or designated people, informing them about the threat and its status. Once the robot detects a bomb using metal detector sensor, gas sensor and electromagnetic sensor the robot manoeuvres its servo motor-driven arm toward the bomb to cut the wire and diffuse it. The arm, controlled through a web server interface, moves the cutter precisely towards the wire. A camera module (ESP32-CAM) provides live video streaming, allowing operators to monitor the robot's progress and ensure accurate actions while maintaining a safe distance.

KEY WORDS: Bomb detection, ESP32-CAM, ESP32, Live video streaming, Real-time alerts, Remote-controlled robot, Explosive sensors, Robotic arm mechanism, Web server interface, Bomb diffusion system.

1.INTRODUCTION

The project’s primary objective is to enhance safety during bomb detection and by utilizing robotic technology, thereby reducing the need for human intervention in dangerous situations. By using a robot, which can be remotely controlled, bomb detection is not only more efficient but also significantly safer. The robot’s array of sensors, including a metal detector, gas sensor, and Hall effect sensor, work together to detect a wide range of explosive devices. The metal detector identifies the metallic components of bombs, while the gas sensor can pick up the chemical signatures of explosive materials. The Hall effect sensor detects magnetic fields, which can indicate the presence of certain explosives. These sensors provide comprehensive

coverage, enabling the robot to scan large, hazardous areas and quickly identify potential threats.

Once a bomb is detected, the system alerts authorities in real-time, allowing for immediate action to be taken. The robot's servo-driven arm is designed to perform bomb disposal tasks such as cutting wires, all of which can be controlled remotely via a web interface. This feature ensures that bomb disposal personnel can neutralize threats without the need to physically approach the device, minimizing the risk of detonation. The ESP32-CAM module adds another layer of safety, providing live video streaming so that operators can observe the situation as it unfolds and make informed decisions based on real time visual data. This combination of advanced sensors, remote control, and live video streaming makes bomb disposal safer, more precise, and more efficient, ultimately saving lives and protecting critical infrastructure. The project represents a significant step forward in the way we approach hazardous environments, using robotics to mitigate human risk in dangerous operations.

2.BLOCK DIAGRAM

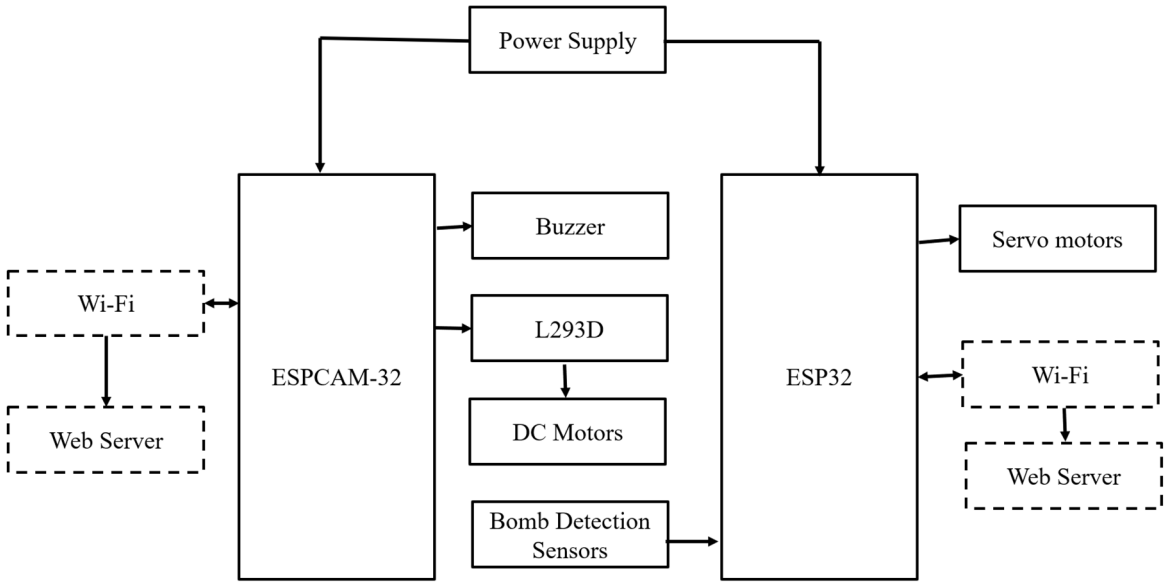

Fig 1. Block Diagram

ESP32-CAM: A low-cost microcontroller module with built-in Wi-Fi and Bluetooth, integrated with an OV2640 camera. It enables real-time video streaming and remote control of the robot over a web interface, allowing operators to monitor and guide the system from a safe distance.

ESP32: The ESP32 is a low-power, dual-core microcontroller with integrated Wi-Fi and Bluetooth, ideal for real-time IoT applications. It enables wireless communication and remote control of the robot through a web-based interface. It is used for sensor integration and handling communication protocols such as sending alerts upon bomb detection.

L293D Motor Driver IC: A dual H-bridge motor driver that allows control of the direction and speed of DC motors. It is used to drive the robot's movement using gear DC motors.

60 RPM Gear DC Motor: These motors provide high torque at low speed, suitable for mobile robot applications. They enable smooth and stable movement of the robot platform during navigation.

MG995 Servo Motor: A high-torque servo motor used to control the robotic arm. Its precise angular positioning capability is leveraged to manoeuvre the cutter toward the bomb's wire for diffusion.

Hall Effect Sensor: Used to detect magnetic fields, assisting in identifying hidden metallic elements in explosive devices.

Metal Detector Sensor: Utilized to detect the presence of metallic components in suspected bombs. It plays a crucial role in the scanning phase of the robot's operation.

Gas Sensor: Capable of detecting the presence of explosive gases in the surrounding area, enhancing the accuracy of bomb detection.

Buzzer: Provides an audible alert to indicate the detection of a bomb or other emergency condition.

Red LED: Acts as a visual indicator for bomb status. It remains ON when a bomb is detected and turns OFF upon successful diffusion.

Rechargeable Battery: Powers the entire robotic system, enabling wireless and mobile operation. It ensures uninterrupted power supply during the robot's deployment.

Working Summary: The robot is mobilized using DC motors controlled by the L293D motor driver, which allows it to traverse challenging terrains and reach potentially dangerous areas. The core functionality of the robot lies in its ability to detect threats through a combination of sensors, including gas sensors for identifying hazardous gases, a metal detector sensor for locating metallic bomb components, and a Hall effect sensor for detecting magnetic field variations. These sensors send signals to the ESP32, the central control unit, which processes the data and initiates corresponding actions.

When a potential threat is detected, the system triggers immediate responses. A buzzer is activated to provide an audible local alert, while the ESP32-CAM streams live video to a remote web interface. This real-time video feed allows operators to monitor the environment from a safe distance and assess the situation visually. Simultaneously, the system communicates alerts via Wi-Fi to relevant authorities, ensuring timely intervention. To safely diffuse explosives, the robot is equipped with a servo motor-driven robotic arm. This arm, controlled remotely through the web interface, performs precise tasks such as wire cutting or component disarming, ensuring the bomb is neutralized effectively.

The ESP32 serves as the brain of the system, coordinating the actions of all components, while the ESP32-CAM enhances situational awareness through continuous live streaming. By

integrating remote navigation, advanced sensing, real-time communication, and robotic precision, the system offers an efficient and reliable solution for bomb detection and diffusion.

The bomb detection and diffusion robot, including the robotic arm for cutting the deactivation wire, has great potential for advancements in public safety and technology. The robotic arm, driven by a precise servo motor and controlled through a web server interface, enables safe and accurate bomb deactivation by cutting the required wire. The visual confirmation of bomb deactivation is provided by the red LED on the bomb turning off, ensuring clear feedback for the operators.

3.HARDWARE MODULE

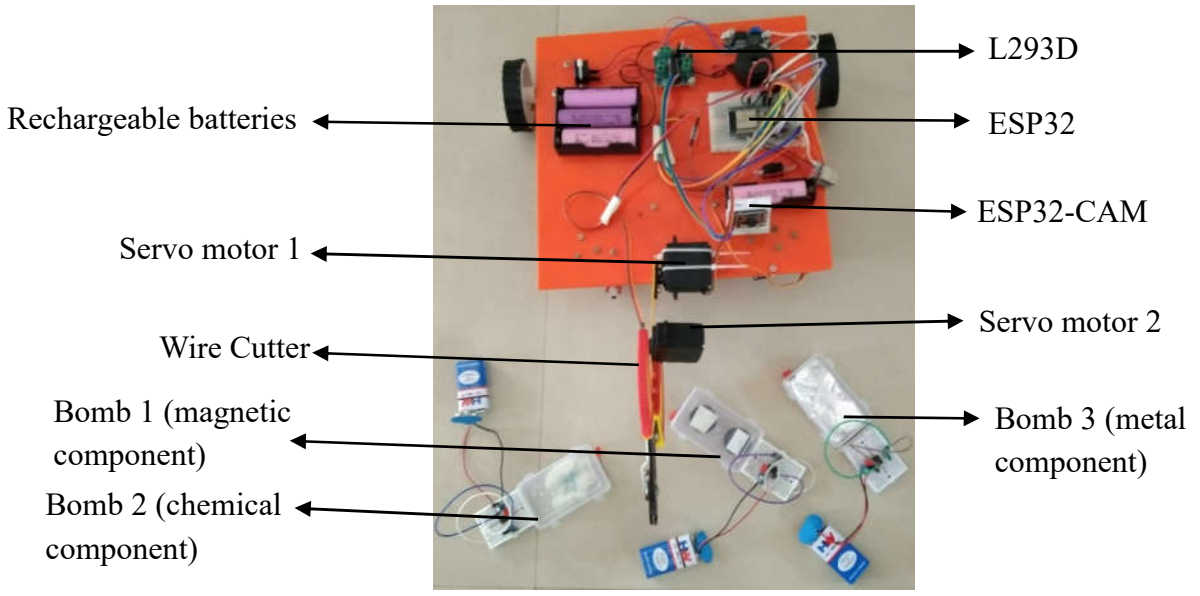

Fig 2(a). Top view

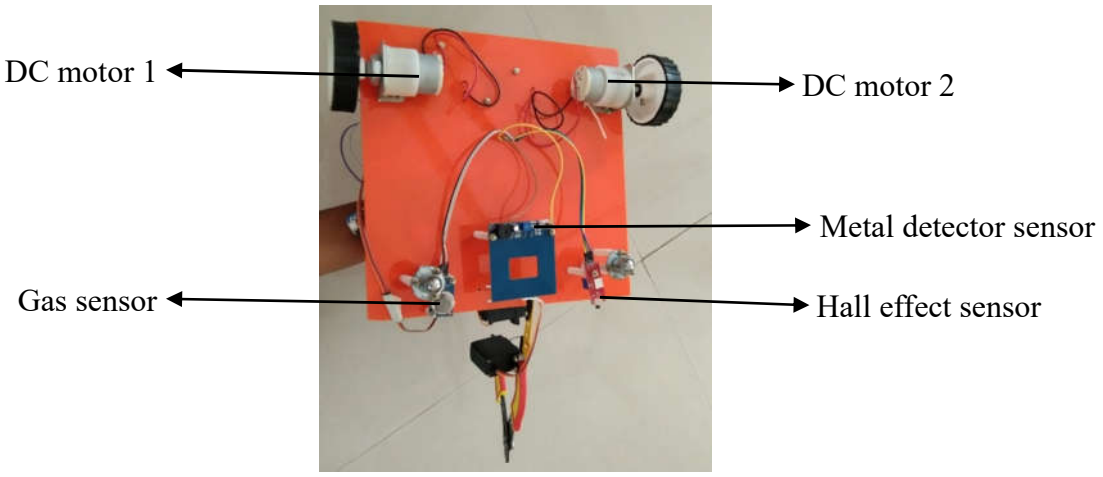

Fig 2(b). Bottom view

After connecting to the Bomb Diffusion Robot and Bomb Diffusion Cam via Wi-Fi using the password 123456789, and supplying 12V from rechargeable batteries to power the robot's movement, ESP32, and camera module users can open a browser on both devices and enter the IP address 192.168.4.1. This opens the respective web servers, providing access to live video streaming with control buttons for robot movement and bomb detection status with robot arm control bar. The robot is then navigated using directional control buttons displayed on the web server interface. The DC motors, controlled by the L293D motor driver, allow the robot to move forward, backward, left, or right, enabling it to explore hazardous environments. The ESP32-CAM provides a real- time video feed of the surroundings, displayed on the web server, to guide the robot's movement accurately and safely.

As the robot moves, sensors such as the gas sensor, Hall effect sensor, and metal detector continuously scan the environment for potential explosive materials. The gas sensor detects the presence of harmful chemical vapours, the Hall effect sensor identifies changes in magnetic fields, and the metal detector identifies metallic components indicative of bombs. The sensor readings are processed by the ESP32, which acts as the central control system. If a threat is detected, the ESP32 triggers the buzzer to emit an immediate audio alert, notifying nearby personnel of the danger. Simultaneously, the system sends real-time alerts and hazard details to the connected mobile devices via the web server. In this stage one version of the project, the focus is on detection. The integration of live video, sensor-based detection, and real-time alerts ensures a reliable and efficient method for identifying potential threats while keeping human operators at a safe distance.

Once the bomb is detected via the live video feed from the ESP32-CAM and identified through the web server interface, the robotic arm is remotely operated by the authorities. Equipped with a precision servo motor and controlled through on-screen buttons, the arm is accurately maneuvered toward the bomb. It then cuts the designated wire, simulating the bomb diffusion process. Successful deactivation is confirmed by the red LED turning off, providing clear visual feedback that the threat has been safely neutralized.

4.TESTING AND RESULTS

The hardware was tested for different cases to observe its operation

4.1 Case I: Normal Operation (No Threat Detected)

In normal conditions, the robot operates without detecting any hazardous substances or abnormalities. All sensors—namely, the gas sensor, Hall effect sensor, and metal detector remain idle, indicating the absence of explosives or dangerous materials. The ESP32 processes real-time sensor data and confirms a secure environment.
During this state, the ESP32-CAM continues to provide uninterrupted live video streaming to the operator's device via a web server interface. Full manual control of the robot's movement is maintained through the web interface, allowing smooth inspection of the area. No alarms or notifications are triggered, and the buzzer remains inactive as the system verifies that no threat is present.

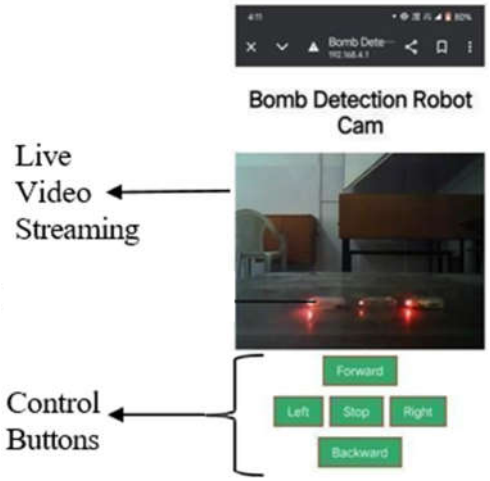

Fig 3.1(a) Web interface showing live video streaming with bomb and robot movement control buttons

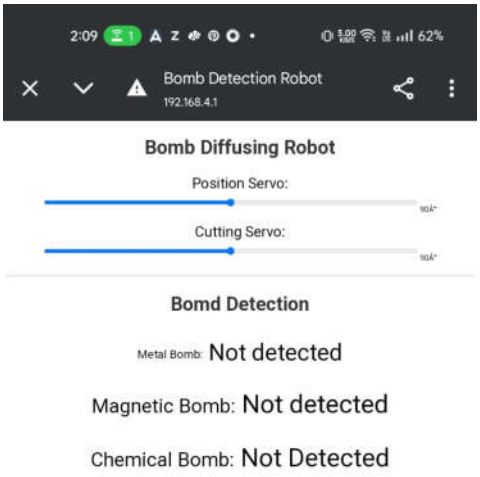

Fig 3.1(b) Web interface showing servo control and bomb detection status.

4.2 Case II: Detection of Bomb Type 1 (Magnetic Field-Based)

This scenario addresses the detection of bombs that emit magnetic fields, typically due to embedded electrical components. The Hall effect sensor, integrated into the system, is responsible for sensing magnetic flux density. As the robot is remotely navigated using the web interface, the ESP32-CAM streams live video footage to the operator for continuous monitoring.

As the robot moves near the suspicious object, the Hall effect sensor identifies the magnetic field generated by the bomb. The sensor transmits this information to the ESP32, which confirms the anomaly. Consequently, the system performs the following actions: Activates the buzzer to provide an audible warning to nearby individuals. Sends real-time alerts and notifications to the operator and connected authorities. Updates the web interface to indicate detection of a magnetically active bomb.

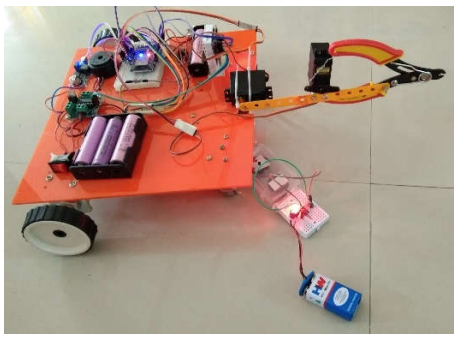

Fig 3.2(A) Robot approaching bomb 1

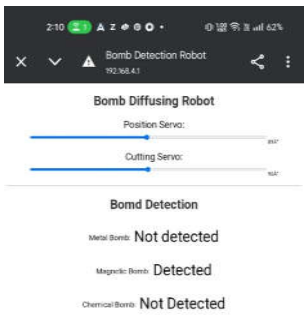

Fig 3.2(B) Web interface showing magnetic bomb detection.

4.3 Case III: Detection of Bomb Type 2 (Metallic Components)

In this case, the bomb consists of metallic elements such as wires, fragments, or casings. The metal detector sensor is tasked with scanning the environment for metallic substances. As the robot continues its path, the ESP32-CAM ensures continuous video streaming, allowing the operator to visually assess the scenario. Upon detecting metal, the metal detector sensor sends a signal to the ESP32. The microcontroller analyses the input and triggers immediate safety protocols: The buzzer is activated to alert nearby personnel. Real-time alerts are sent via Wi-Fi to the operator's device and to authorities, enabling a prompt emergency response.

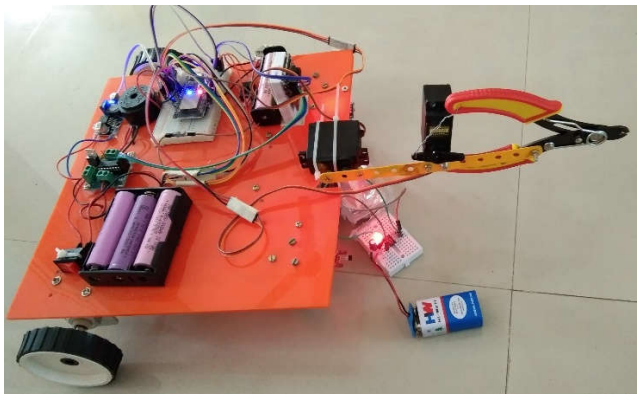

Fig 3.3(A) Robot approaching bomb 2

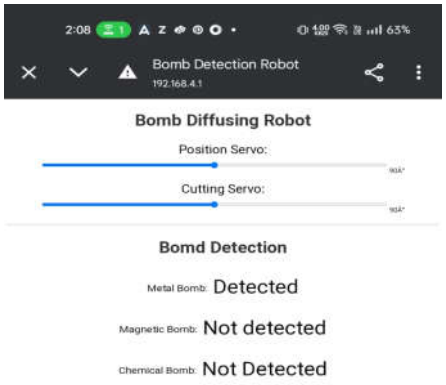

Fig 3.3(B) Web interface showing metallic bomb detection.

4.4 Case IV: Detection of Bomb Type 3 (Chemical Components)

In this scenario, the bomb emits chemical vapours or gases commonly associated with explosive compounds. The gas sensor embedded in the robot is designed to detect these volatile substances. As the robot patrols the environment, live footage is streamed via the ESP32-CAM to the operator. When the gas sensor identifies the presence of hazardous chemicals, it sends the signal to the NodeMCU, which then: Triggers the buzzer to issue an audible alert. Sends real-time alerts and threat data to the operator's device and to relevant emergency services.

4.5 Case 5: Bomb Diffusion via Robotic Arm Control

Once the bomb is detected using the live video feed from the ESP32-CAM and identified through the web server interface, the authorities remotely control the robotic arm. The arm, equipped with a servo motor and operated through control buttons on the web server, is maneuvered precisely towards the bomb. The arm cuts the designated wire, simulating the bomb diffusion process. Successful deactivation is indicated by the red LED turning off, confirming that the bomb has been safely neutralized.

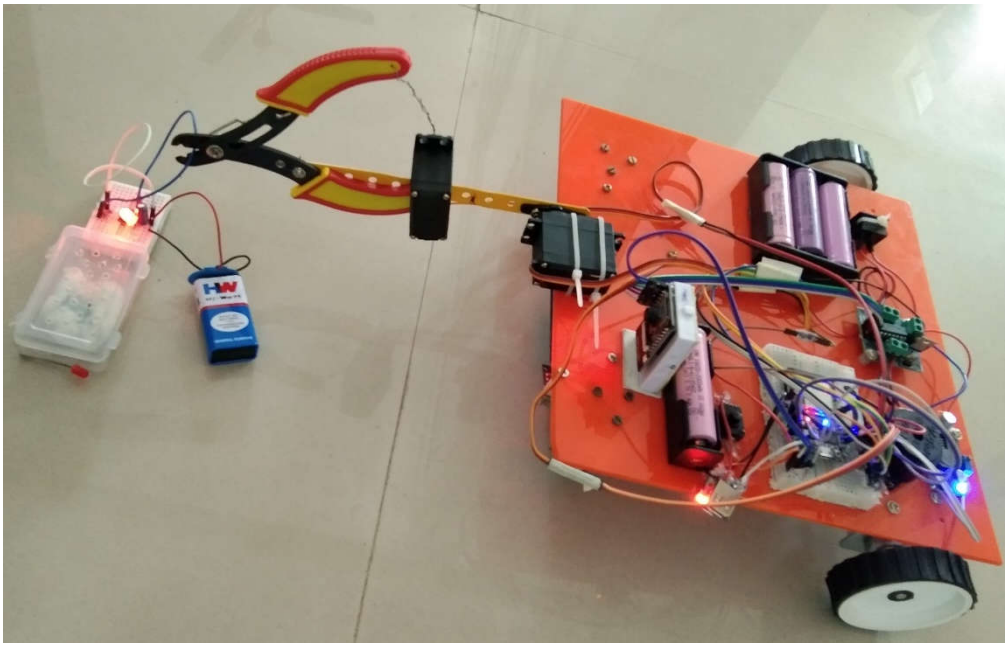

Fig 4.5 Robotic arm operation showing wire cutting for bomb diffusion with red LED indicating active bomb status.

5.CONCLUSION

The Bomb Detection and Diffusion Robot with Live Alerts and Video Streaming offers a reliable and efficient approach to addressing safety challenges in hazardous environments. By integrating gas, Hall effect, and metal detector sensors, the system ensures effective identification of potential explosive threats. The inclusion of the ESP32-CAM module enables real-time video streaming, providing operators with continuous visual feedback for remote monitoring and control.

The robot's operations are managed through a web server interface, allowing users to navigate the system and respond to threats with precision and ease. At the core of the system, the ESP32 microcontroller efficiently processes sensor data and coordinates real-time alerts to both operators and authorities, ensuring swift and informed responses.

In addition to threat detection, the robot incorporates an actuator-based solution for bomb diffusion. A servo motor-driven robotic arm, operated through the web interface, is used to simulate the safe deactivation of a detected bomb by precisely cutting a designated wire. The successful completion of this task is confirmed through a red LED indicator, which turns off upon simulated neutralization.

This project demonstrates a practical, low-cost, and scalable solution for enhancing security in high-risk areas. The combination of autonomous threat detection, real-time communication, and remote bomb diffusion establishes a comprehensive framework for modern threat mitigation, reducing the need for direct human intervention and improving overall operational safety.

6.FUTURE SCOPE

Future iterations of the bomb detection and diffusion robot can aim to enhance the robotic arm's durability, flexibility, and precision, allowing it to effectively handle a wider range of bomb types and deactivation scenarios. The integration of additional sensors—such as temperature, vibration, and radiation sensors—can further improve environmental hazard detection and situational awareness. Moreover, incorporating advanced technologies like machine learning for predictive threat analysis, autonomous navigation, and real-time 3D mapping can significantly increase the system's versatility. These advancements will not only optimize the robot for bomb disposal but also extend its applications to industrial safety, disaster response, and hazardous material handling—making it a comprehensive solution for operating in high-risk environments.

7.ACKNOWLEDGMENT

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