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Smart Robot for Detection and Diffusion of Explosives and Hazardous Gas Sensing

Vaishnavi devi J[1], K.Yogitha[2]

[1,2]Department of Electronics and Communication Engineering, Sathyabama Institute of Science and Technology, Chennai, India

Abstract
This study describes the development of an intelligent robotic system designed to detect and neutralize explosive threats while enabling remote monitoring and automated hazard analysis. The proposed system combines embedded hardware components with machine learning techniques to improve operational safety in high-risk environments. The robotic platform integrates multiple functional units, including a toxic gas sensor for monitoring harmful atmospheric conditions, a GPS module for accurate location identification, and an RF-based communication system that allows wireless control from a safe distance. An onboard buzzer provides instant alerts whenever a threat is detected. For physical handling of suspected explosive objects, a mechanically controlled robotic gripper is incorporated to ensure careful and secure manipulation. Visual surveillance is achieved using an ESP32-CAM module, which streams live video to the operator. The captured images are processed using a custom-trained machine learning model capable of identifying weapons or suspicious objects in real time. In addition, a gas classification model developed in Python is integrated with a cloud-based platform to analyze environmental readings. The system categorizes detected gases into three levels—safe, warning, and dangerous—and presents the results through graphical visualization for easier interpretation. Whenever a potential threat is identified, automated email notifications are generated, including the exact GPS coordinates and the corresponding risk level. By combining real-time sensing, intelligent classification, and remote accessibility, the proposed semi-autonomous robotic solution enhances operational safety and is particularly suitable for military operations, disaster management scenarios, and hazardous area surveillance.

Keywords: Explosive detection, toxic gas sensing, ESP32- CAM, RF control, GPS alert system, robotic gripper, machine learning, Cloud platform, remote surveillance.

1. Introduction

Maintaining safety in environments exposed to explosives and toxic substances has become a major concern across defense operations as well as civilian security systems. In response to these challenges, an intelligent robotic platform has been designed to perform threat detection, environmental monitoring, and controlled neutralization of hazardous objects. The system integrates multiple sensing technologies with real-time communication and machine learning algorithms to enhance reliability and operational safety.

The mobility and manipulation of the robot are managed through an RF-based wireless control system, allowing operators to function from a secure distance. A GPS module is incorporated to provide precise

geographical coordinates whenever a suspicious object or hazardous condition is identified. Environmental monitoring is achieved through a toxic gas sensor, and the collected data is processed using a Python-based machine learning model connected to a cloud database. Based on learned patterns, the system categorizes atmospheric conditions into three predefined levels: safe, cautionary, or critical.
For visual intelligence, the robot employs an ESP32-CAM module that streams live video to the control unit. The video feed is analyzed using a trained object detection model capable of recognizing weapons or potentially dangerous items within the surroundings. Compared to conventional bomb disposal methods that require close human interaction, the proposed system significantly reduces direct exposure to risk by combining remote operation with automated threat assessment.
In situations where a threat is detected, the system automatically generates email notifications containing classification results and exact GPS coordinates to ensure rapid response. A robotic gripper mechanism is integrated to handle explosive materials with controlled precision, while a tracked wheel configuration enables stable navigation across uneven and challenging terrain.
Overall, the proposed framework represents a unified integration of hardware components and intelligent software algorithms. Its adaptable design makes it appropriate for deployment in defense zones, crowded public locations, and disaster-affected regions, thereby contributing to modern safety management and surveillance application

2. Literature Review

Recent advancements in robotic explosive detection, landmine identification, and hazardous gas monitoring systems have significantly improved safety in military and industrial environments. Researchers have explored various approaches combining wireless communication, robotic manipulation, sensor integration, and artificial intelligence for enhancing operational efficiency and reducing human risk. This section presents a systematic review of major contributions in the domain of bomb detection, landmine identification, and intelligent robotic safety systems.

Table 1: Comparative Analysis of Explosive Detection and Robotic Safety Systems (2017–2024)

Author(s) & Year	**Journal / Conference**	**System Focus**	**Key Technologies**	**Major Contributions**	**Identified Gaps / Limitations**
Gnanaprakasam et al., 2023	IEEE ACCAI	Smart soldier supportive wireless robot	Zigbee, toxic gas sensors, metal detection, fire hazard sensors	Designed for hazardous operations like bomb disposal, surveillance, and search and rescue	Semi-autonomous control limits adaptability in dynamic combat environments
Thomas & Aruna, 2017	IEEE IGEHT	Unmanned Ground Vehicle (UGV) for surveillance and bomb detection	Haptic arm technology, Zigbee communication, toxic gas and metal sensors	Improved precision in explosive handling and surveillance	Operates in semi-autonomous mode; lacks AI-driven automation

Bale et al., 2023	IEEE ICCES	Explosive projectile detection robot	Arduino control, metal detector, robotic arm, Wi-Fi/Zigbee	Cost-effective bomb identification and disposal robot	Manual operation limits real-time adaptability
Chowdhury et al., 2021	IEEE ICREST	Bomb defusing robot with live streaming	Dual camera interface, Wi-Fi/Zigbee communication	Integrated real-time surveillance with robotic armfor safe disposal	No intelligent object detection; relies on manual control
Shyam et al., 2023	IEEE ACCAI	Bomb identification and defusing robot	Arduino Uno, wireless module, hand gesture	Intuitive gesture-based control for precision	Reliance on manual gestures limits autonomous
			recognition	handling	functionality
Srikar et al., 2023	IEEE ICICACS	IoT-based surveillance robot with bomb diffusion	ESP32, night vision IR camera, robotic arm	Remote monitoring with IoT integration	Manual robotic arm control restricts autonomous decision-making
Ismail et al., 2020	IEEE ICICCS	Military Support and Rescue Robot (MSRR)	Zigbee communication, wireless camera, sensor circuit	Semi-autonomous UGV for reconnaissance and bomb disposal	Limited operational range due to Zigbee communication
Krishnamoorthy et al., 2024	IEEE ACCAI	Smart bomb detection and diffusing robot	NodeMCU, robotic arm, metal detector, GPS location sharing	Real-time monitoring with location-based alert system	Manual robotic arm limits autonomous functionality
Navare et al., 2022	IEEE ICCES	Arduino-based bomb detection and disposal system	RF-controlled module, metal detection sensor, wireless camera	Enhanced operator safety through remote control	Limited autonomous functionality and adaptability
Chaubey et al., 2023	IEEE MAC	Spying and bomb disposal robot	Android-based Blynk interface, Zigbee communication, GSM with GPS	Integrated live surveillance and automatic alert system	PVC-based construction may limit durability
Awad et al.,	Journal of	Autonomous	ROS, SLAM	Autonomous	Raspberry Pi

2022	International Society for Science and Engineering	landmine detection robot	mapping, IMU, LIDAR, Raspberry Pi	navigation with obstacle avoidance	limits real-time processing efficiency
Jomartov et al., 2023	SN Applied Sciences	Cable-driven parallelrobot for landmine detection	Flexible cables, vehicle- mounted metal detector	High-speed detection with improved payload-to-weight ratio	Workspace limitation in X-Y plane reduces coverage efficiency
Najjaran & Goldenberg, 2005	Industrial Robot Journal on Mechatronics	Dual-arm mobile manipulator for landmine Detection for landmine detection	Laser rangefinder, ultrasonic sensors, terrain scanning motion simulation	Human-like landmine detection using articulated arms rough terrains	Dependence on operator-controlled vehicle limits full autonomy unpredictability may affect performance
Dasgupta et al., 2015	Journal of Robotics	Multi-robot autonomous landmine detection system (COMRADES)	Multi-robot task allocation, sensor fusion	Distributed detection improves accuracy and coverage	Real-time coordination challenges among robots
Shimoi et al., 2001	ICCAS Conference	IR camera-based landmine detection	Infrared thermal imaging	Detection of buried mines via temperature differences	Reduced effectiveness in minimal temperature contrast environments
Sipos et al., 2017	IEEE ELECO	Drone- mounted ground penetrating radar (GPR)	UWB antenna, pulse generator, air-coupled GPR	Non-contact scanning improves safety	Signal interference and terrain adaptability issues
Hasselmann et al., 2024	IEEE ICRA Workshop	Multi-robot explosive detection system	Electromagnetic induction, GPR, X-ray imaging, UAV + UGV	Advanced sensor fusion for explosive classification	Real-time coordination between UAVs and UGVs remains challenging

2.1 Critical Analysis

An analysis of existing studies indicates that notable advancements have been achieved in the areas of robotic bomb neutralization, landmine identification, and surveillance technologies. Early developments largely concentrated on basic metal detection techniques and manually operated robotic manipulators. In contrast, more recent research incorporates advanced methodologies such as Simultaneous Localization and Mapping (SLAM), coordinated multi-robot frameworks, and sensor fusion strategies to enhance detection accuracy and navigation efficiency. Despite these technological improvements, several limitations continue to persist in current systems. One major gap is the insufficient incorporation of deep learning models for real-time object detection in explosive handling platforms. While image processing has been explored, fully integrated AI-based recognition systems remain limited. Additionally, many existing solutions address specific functionalities—such as gas detection, landmine identification, or surveillance—independently, rather than combining them into a unified framework. Another challenge lies in the continued dependence on manual or semi-manual control mechanisms in numerous bomb disposal robots, which can increase operator workload and response time. Communication constraints, particularly in Zigbee-based architectures, also restrict operational range and data transmission reliability in certain deployments. Furthermore, only a limited number of systems provide cloud-connected infrastructure for real-time monitoring, automated alerts, and remote data visualization.

Overall, although individual technologies have matured significantly, the development of a comprehensive, multi-functional robotic platform that integrates deep learning-based object detection, toxic gas monitoring, GPS-supported alert mechanisms, cloud connectivity, and all-terrain mobility for safe explosive handling remains comparatively underexplored. Addressing this integration gap forms the core motivation for the proposed system.

3. Architecture of the Proposed Smart Robotic Explosive Detection and Disposal System

Figure 1. layered Architecture of the Smart Robot System

The proposed robotic framework follows a structured multi-layer architecture designed to combine sensing, intelligent analysis, communication, and user interaction into a unified safety platform. The objective of this design is to enable real-time threat awareness, automated decision support, and safe remote intervention in high-risk environments such as defense zones, disaster-affected regions, and industrial areas exposed to hazardous chemicals.

By dividing the system into distinct functional layers, the architecture improves modular development, easier scalability, and reliable operation under dynamic field conditions. The complete framework is organized into four main layers: the Perception Layer, the Intelligence and Processing Layer, the Communication Layer, and the Application and Alert Layer.

3.1 Perception Layer

The perception layer serves as the physical interface between the robot and its surrounding environment. It is responsible for collecting environmental, positional, and visual data while also executing mechanical operations required for explosive handling.

This layer incorporates a metal detection unit capable of identifying buried or concealed metallic threats. A multi-gas sensing module continuously monitors harmful gases such as carbon monoxide, carbon dioxide, methane, and ammonia. For visual surveillance, an ESP32-CAM module captures live image frames used for object recognition and remote inspection. A GPS module determines accurate geographic coordinates whenever a suspicious object or hazardous condition is identified. The system also integrates a servo-driven robotic gripper to safely manipulate explosive materials. High-speed drive motors combined with a tracked wheel mechanism enable smooth movement across uneven and rough terrains. All collected data from this layer is forwarded to the processing unit for intelligent analysis and decision-making.

3.2 Intelligence and Processing Layer

This layer performs data analysis, threat classification, and robotic control.

Core elements include:

Convolutional Neural Network (CNN) – Trained on a large labeled dataset to detect weapons, drones, missiles, and explosive-related objects in real time.

Gas Classification Model – Categorizes gas concentration levels into Safe, Warning, and Dangerous based on predefined thresholds.

Arduino Control Unit – Manages locomotion and gripper mechanisms.

NodeMCU and ESP8266 Modules – Provide IoT connectivity for cloud communication.

The CNN processes image frames from the ESP32-CAM, while gas sensor readings are evaluated simultaneously. If abnormal conditions are detected, the system activates alert protocols.

3.3 Communication Layer

This layer ensures secure and reliable data transmission between the robot, cloud infrastructure, and remote operators.

Communication framework includes:

433 MHz RF Transmitter and Multi-Channel Receiver – Enables wireless remote control of robot movement and gripper operations.

Wi-Fi-based IoT Communication (NodeMCU) – Supports real-time cloud synchronization.

Firebase Realtime Database – Stores gas readings and system status for remote monitoring.

Automated Email Notification System – Sends alerts containing threat details.

Upon threat detection, the system transmits:

- GPS coordinates
- Threat classification result

- Timestamped alert data

3.4 Application and Alert Layer

Key functionalities include:

- **Live ESP32-CAM Video Feed** for manual visual inspection.
- **Cloud-based Dashboard** for monitoring gas concentration trends.
- **Graphical Data Visualizations** such as bar graphs, pie charts, heatmaps, and time-series plots.
- **Automated Email Alerts** for unauthorized object detection and gas threshold breaches.

The integration of cloud-based analytics with automated alert mechanisms enhances situational awareness and ensures rapid response capability in emergency scenarios.

4. Proposed System

Existing robotic systems typically focus on individual functionalities such as metal detection, surveillance, or manual bomb disposal. Many lack integrated AI-based object recognition and real-time cloud monitoring capabilities.

The proposed system introduces:

- Deep learning-based visual threat detection
- Toxic gas monitoring with classification
- GPS-enabled automated alerting
- IoT cloud integration
- All-terrain robotic mobility with explosive handling capability

This integrated architecture improves automation, reduces manual dependency, and enhances operational safety in high-risk environments.

Table 2: Comparison Between Existing Systems and Proposed Smart Robotic System

Feature	**Traditional Bomb Disposal Robots**	**IoT Surveillance Robots**	**Landmine Detection Robots**	**Proposed Smart Robotic System**
Metal Detection	Yes	Yes	Yes	Yes
Toxic Gas Detection	No	Limited	No	Yes
Deep Learning-Based Object Detection	No	No	No	Yes
Real-Time Video Surveillance	Limited	Yes	Limited	Yes
GPS-Based Location Alert	Limited	Yes	Yes	Yes
Cloud-Based Data Monitoring	No	Limited	No	Yes
Automated Email Notification	No	Limited	No	Yes
Integrated Multi-Layer Architecture	No	No	No	Yes
Remote RF-	Yes	Yes	Yes	Yes

Based Mobility Control				
All-Terrain Navigation Capability	Limited	Limited	Yes	Yes

4.1 Novelty Justification

A comparative evaluation of existing systems indicates that many robotic platforms are developed to perform specific tasks such as metal detection, surveillance monitoring, or landmine identification independently. Although certain models incorporate GPS tracking or wireless communication, they often lack integrated deep learning-based visual recognition and combined toxic gas monitoring within a single unified framework.

The proposed system distinguishes itself through the following integrated features:

CNN-based real-time detection of weapons and explosive-related objects

Multi-level gas classification categorizing environmental conditions into Safe, Warning, and Dangerous levels

IoT-enabled cloud monitoring using Firebase for continuous data synchronization

Automated email notifications including GPS coordinates and threat details

All-terrain robotic mobility with RF-based remote control and gripper mechanism

By consolidating sensing, intelligence, communication, and actuation into one architecture, the system enhances situational awareness, reduces response time, and significantly minimizes human exposure in hazardous zones. This level of integration strengthens operational safety beyond conventional bomb disposal robots.

5. Methodology

The methodology of the proposed Smart Robotic Explosive Detection and Disposal System integrates hardware design, deep learning-based object detection, IoT-enabled gas monitoring, and remote-controlled robotic actuation. The system is developed through a structured approach consisting of hardware implementation, software intelligence modeling, and integrated block-level architecture. The following subsections describe each component in detail.

5.1 Software Methodology – Defence Object and Gas Detection

A. Dataset Preparation

- A custom dataset containing more than 50,000 labeled images was prepared.
- Images were categorized into authorized and unauthorized defence-related objects such as tanks, drones, and missiles.
- The dataset was divided into training (43,958 images), validation (2,948 images), and testing (2,793 images) subsets to ensure balanced evaluation.

B. Preprocessing

- All images were resized to a uniform resolution (e.g., 224 × 224 pixels).
- Pixel values were normalized to a range between 0 and 1.
- Data augmentation techniques such as rotation, horizontal flipping, and zooming were applied to improve generalization and reduce overfitting.

C. CNN Model Architecture

- A Convolutional Neural Network (CNN) was implemented using Keras with a TensorFlow backend.
- The architecture included multiple convolutional layers with ReLU activation.

- Max-pooling layers were used for dimensionality reduction.
- Dropout layers were incorporated to prevent overfitting.
- Fully connected dense layers were used for classification.
- A sigmoid activation function was applied in the output layer for binary classification.

D. Model Training and Evaluation

- The Adam optimizer was used for model training.
- Binary cross-entropy was selected as the loss function.
- Performance metrics included accuracy, precision, recall, F1-score, and confusion matrix analysis.
- The trained model was saved as **defense_binary_model.h5** for deployment.

E. Deployment

- The trained model was deployed using Google Colab.
- Google Drive integration enabled real-time image input testing.
- When an unauthorized object is detected, the system generates the alert message: **"Danger: Unauthorized object detected."**

F. Toxic Gas Data Management

- Simulated gas readings for CO, CO_2, NH_3, and CH_4 were generated.
- Each dataset entry included timestamped concentration values.
- Data was uploaded to Firebase Realtime Database.
- The system supports both real-time data updates and historical data retrieval for monitoring and analysis.

5.2 Hardware Methodology – Toxic Gas Detection

Gas Sensor Simulation

- A synthetic dataset was created to simulate readings for CO, CO_2, CH_4, and NH_3 gases.
- Each entry included concentration levels and timestamps.

Data Processing and Thresholding

- Python-based scripts processed the simulated gas readings.
- Threshold values were defined for each gas type.
- Conditions were classified into safe and hazardous categories based on limits.

Cloud Connectivity

- Processed data was transmitted to Firebase database.
- Real-time monitoring and historical data access were enabled.
- Cloud storage supports safety audits and further analytical modeling.

Alert Mechanism

- When gas concentration exceeded predefined safety thresholds, the system triggered an alert.
- Warning notifications enabled immediate user intervention.

5.3 Robotic Methodology – Explosive Detection and Disposal

Mobility and Terrain Adaptability

- The robot is designed with high ground clearance.
- Tracked wheels support stable navigation on uneven surfaces.
- The system can operate in forests, rocky terrains, and disaster-affected zones.

Metal Detection

- A metal detector continuously scans the operational path.

- Metallic signatures indicate potential explosive threats.

GPS Tracking and Email Notification

- Upon detecting a metallic object, GPS coordinates are captured.
- The location is automatically transmitted via email.
- Timestamp information is included for field reference.

Remote Bomb Disposal via RF Control

- A 4-channel RF relay module enables wireless command transmission.
- The robotic gripper manipulates explosive components from a safe distance.
- Operators can control movement and disposal functions remotely.

Remote Operation and Safety

- RF-based commands ensure operator safety in hazardous environments.
- Modular architecture supports stable performance under unstable conditions.
- Human exposure to explosive threats is significantly minimized.

This methodology establishes a coordinated integration of artificial intelligence, IoT communication, and robotic automation to create a reliable and intelligent defence support system.

5.4 Block Diagram

The IoT subsystem is centered around the ESP8266 microcontroller, which acts as the primary integration unit.

Core integrations include:

- Metal detector for identifying concealed metallic objects
- Gas sensor for monitoring toxic and flammable gases
- ESP32-CAM module for real-time visual data acquisition
- GPS module for location tracking
- Cloud connectivity via ESP8266 for remote monitoring and data storage

All collected data is transmitted to the cloud platform, enabling environmental awareness, system monitoring, and situational intelligence.

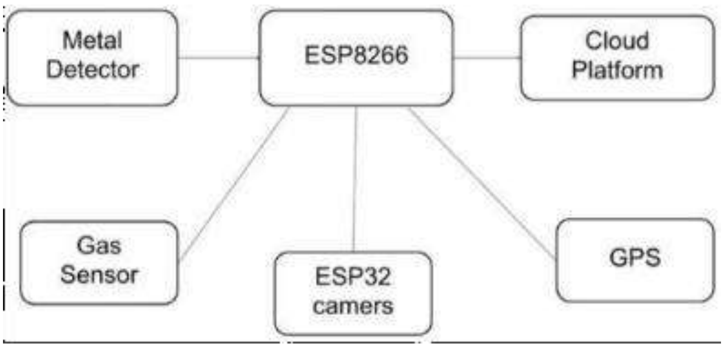

Figure 2. IoT Functions

The mobility control subsystem manages robotic movement and object interaction.

Functional components include:

- User-controlled gripper activation button
- Gripper command processing unit
- RF transmitter and receiver pair for wireless control

- Motor driver for executing navigation commands

Movement instructions are transmitted wirelessly and executed by the motor driver, enabling precise control of locomotion and manipulation tasks. This configuration ensures responsive operation in sensitive and high-risk environments.

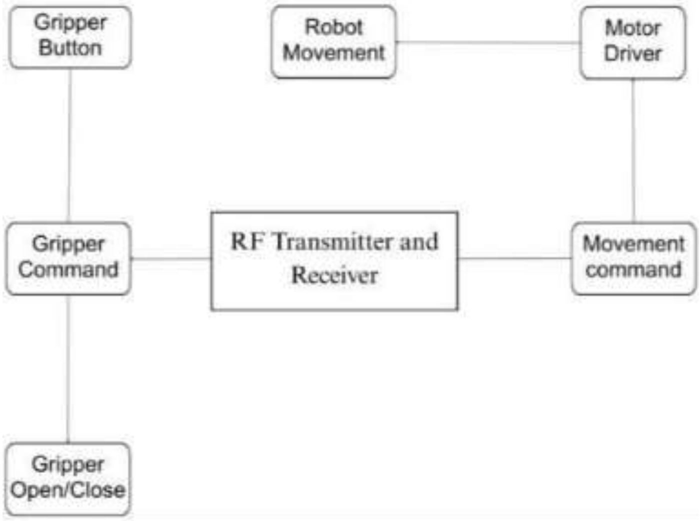

Figure 3. Mobility Control

6 Result And Discussion

The fully assembled bomb and landmine detection and disposal robot is illustrated in Figures 4 and 5. The system is constructed on a rigid chassis and powered by 1000–3000 RPM drive motors, enabling stable movement across uneven and challenging terrains. The integration of sensing, mobility, and communication modules demonstrates the practical implementation of the proposed architecture.

The robot incorporates:

- A **metal detector** for identifying concealed explosive materials
- A **gas sensor module** for detecting harmful gases such as methane and carbon dioxide
- A **servo-driven robotic gripper** for safe handling and neutralization of explosive devices

This configuration enables both detection and controlled disposal operations from a safe distance.

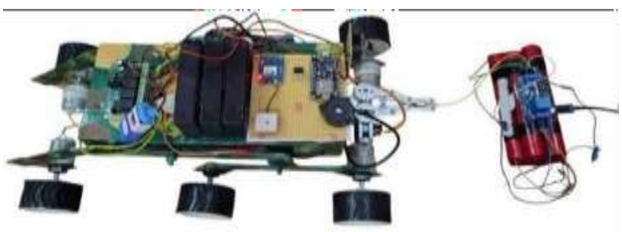

Figure 4. Top View Of The Robot

Figure 5. Side View Of The Robot

The top and side views highlight the structural integration of sensors, camera module, gripper mechanism, and drive system within a compact robotic platform.

For remote operation, the system utilizes:

- An **Arduino-based 433 MHz RF transmitter**
- A **4-channel RF receiver** for wireless control
- An **ESP32-CAM module** for real-time video streaming
- A **NodeMCU module** for IoT communication and data handling
- A **12V battery supply** with LM7805 voltage regulator for stable power distribution

This integrated configuration ensures reliable navigation, monitoring, and control during hazardous operations.

Step-3 Disconnection

Figure 6. Bomb Detection And Disposal

Figure 6 illustrates the operational steps involved in bomb identification and disposal. The robot first detects a suspicious object using the metal detector. Once confirmed, the gripper mechanism is activated remotely to safely disconnect or isolate the explosive component, thereby preventing detonation.

Metal Detection Gas Detection

Figure 7. Landmine and Hazardous Gas Detection

The landmine detection process operates through continuous scanning of the terrain using the metal detection unit. Simultaneously, the gas sensor monitors environmental conditions. Upon detecting hazardous gas levels, the system automatically communicates alert information through the network for immediate-response.

Toxic Gas Monitoring Results

The gas detection subsystem classifies environmental conditions using predefined concentration thresholds combined with cloud-based data management.

The system performs the following:

- Uploads timestamped gas readings to Firebase
- Classifies readings into **Safe**, **Warning**, and **Dangerous** categories
- Generates visual analytics for interpretation
- Triggers alerts when thresholds are exceeded

Graphical visualizations include:

- Bar charts
- Pie charts
- Line graphs
- Heatmaps

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```
safe_df = df[df['Status'] == 'Safe']
safe_df
```

	Timestamp	Sensor ID	CO (ppm)	NO_2 (ppb)	SO_2 (ppb)	O_3 (ppb)	H_2S (ppb)	NH_3 (ppb)	Status
89	2024-04-09 12:30:00	GAS003	5.69	42	15	30	1	22	Safe
119	2024-04-12 12:30:00	GAS002	2.73	31	7	50	3	12	Safe
121	2024-04-13 08:30:00	GAS002	4.66	58	5	67	4	20	Safe
135	2024-04-14 10:30:00	GAS001	6.71	55	6	59	4	28	Safe
143	2024-04-15 09:30:00	GAS002	1.80	52	6	30	6	34	Safe
145	2024-04-15 10:30:00	GAS003	5.44	28	13	66	2	30	Safe

Figure 8. Output Of Safe State

The Fig.8 output shows gas readings categorized as **Safe**, indicating acceptable environmental conditions. The system correctly identifies periods where no immediate threat is present.

```
warning_df = df[df['Status'] == 'Warning']
warning_df
```

	Timestamp	Sensor ID	CO (ppm)	NO_2 (ppb)	SO_2 (ppb)	O_3 (ppb)	H_2S (ppb)	NH_3 (ppb)	Status
0	2024-04-01 08:00:00	GAS002	2.22	67	16	69	2	96	Warning
2	2024-04-01 09:00:00	GAS001	3.58	70	6	61	1	33	Warning
8	2024-04-01 12:00:00	GAS003	9.37	33	12	31	7	37	Warning
11	2024-04-02 08:30:00	GAS002	8.37	80	7	24	5	57	Warning
12	2024-04-02 09:00:00	GAS003	3.48	24	7	62	4	91	Warning
13	2024-04-02 09:30:00	GAS002	5.62	43	7	35	3	91	Warning
15	2024-04-02 10:30:00	GAS001	2.93	71	12	39	1	78	Warning
29	2024-04-03 12:30:00	GAS001	6.81	61	8	31	5	57	Warning
34	2024-04-04 10:00:00	GAS003	6.89	31	16	38	2	98	Warning
36	2024-04-04 11:00:00	GAS001	5.56	47	16	67	2	73	Warning
42	2024-04-05 09:00:00	GAS001	9.34	22	9	40	2	26	Warning
55	2024-04-06 10:30:00	GAS001	5.68	39	10	52	1	73	Warning
57	2024-04-06 11:30:00	GAS002	1.82	64	11	27	7	67	Warning
58	2024-04-06 12:00:00	GAS002	10.40	58	7	61	6	33	Warning
75	2024-04-08 10:30:00	GAS003	9.12	55	11	41	5	76	Warning
76	2024-04-08 11:00:00	GAS001	7.52	82	7	47	6	74	Warning
78	2024-04-08 12:00:00	GAS002	10.32	72	14	62	2	87	Warning
79	2024-04-08 12:30:00	GAS002	1.25	39	15	18	8	76	Warning

Figure 9. Output Of Warning State

This portion of the output highlights gas readings that fall into the "Warning" category. These values are not critically dangerous but are high enough to warrant caution. The model flags these readings to help anticipate future risks, enabling timely preventive action and enhancing safety monitoring.

```
danger_df = df[df['Status'] == 'Dangerous']
danger_df
```

	Timestamp	Sensor ID	CO (ppm)	NO_2 (ppb)	SO_2 (ppb)	O_3 (ppb)	H_2S (ppb)	NH_3 (ppb)	Status
1	2024-04-01 08:30:00	GAS002	7.45	118	20	27	2	38	Dangerous
3	2024-04-01 09:30:00	GAS002	2.58	49	16	29	7	142	Dangerous
4	2024-04-01 10:00:00	GAS001	6.62	61	30	49	4	79	Dangerous
5	2024-04-01 10:30:00	GAS003	18.53	109	5	35	1	35	Dangerous
6	2024-04-01 11:00:00	GAS003	11.30	115	5	28	9	98	Dangerous
7	2024-04-01 11:30:00	GAS001	13.88	52	21	40	10	129	Dangerous
9	2024-04-01 12:30:00	GAS001	11.11	71	21	58	4	125	Dangerous
10	2024-04-02 08:00:00	GAS002	16.12	120	16	34	1	31	Dangerous
14	2024-04-02 10:00:00	GAS003	19.14	45	17	20	3	42	Dangerous
16	2024-04-02 11:00:00	GAS003	17.51	101	6	59	10	99	Dangerous

Figure 10. Output Of Danger State

The dangerous state output pinpoints the most severe gas readings—those that surpass hazardous limits. These entries reflect critical danger and would typically trigger immediate alerts to the users. The classification helps in identifying unsafe conditions that may require evacuation or emergency intervention. This comparative output ranks the three states (Safe, Warning, Dangerous) from least to most critical. This allows stakeholders to quickly identify whether most conditions are manageable or if dangerous gas levels dominate the dataset. It supports decisions regarding the urgency and extent of safety measures required in Fig.11.

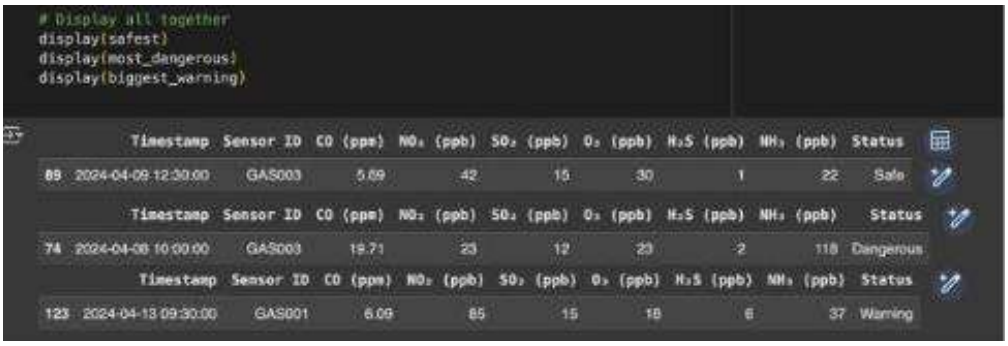

Figure 11. Output Of Comparison Of Each State

The pie chart illustrates the proportional distribution of each gas safety state. This format is especially useful for showing the share of each category at a glance, helping users quickly understand whether the environment being monitored is mostly safe or hazardous.

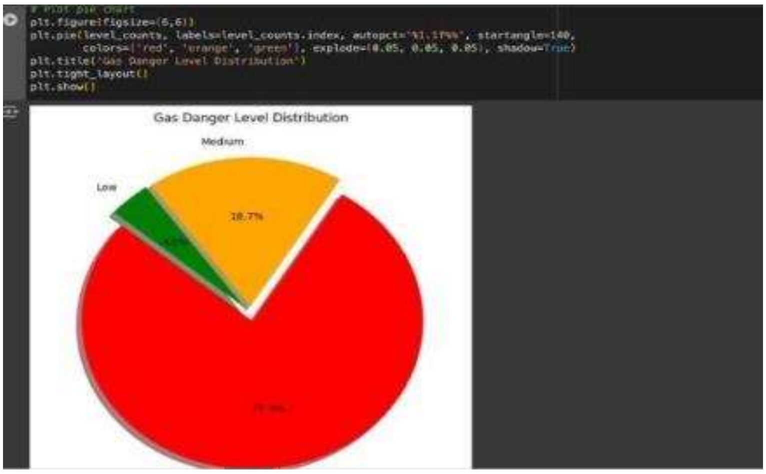

Figure 12. Gas Danger Level Distribution

This line chart tracks the progression of gas danger levels over time. It captures rises and falls in gas readings, making it easier to spot cyclical patterns or anomalies. This chart is crucial for long-term monitoring and predicting future spikes in toxicity.

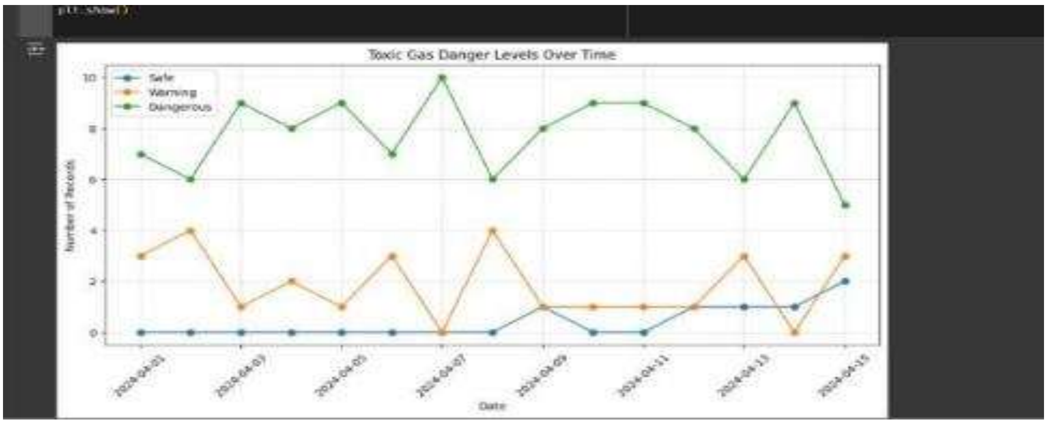

Figure 13. Gas Level Distribution In Line Chart

The line graph tracks gas concentration variations over time. It helps identify patterns, spikes, or anomalies, supporting predictive safety monitoring.

Weapon Detection Results

The weapon detection subsystem uses a trained CNN model to identify unauthorized defense-related objects from image inputs.

System capabilities include:

- Real-time image classification
- Bounding box generation around detected objects
- Confidence score display
- Automatic email alert generation
- Live camera link sharing upon detection

Figure 14. Prediction Of Output with Weapon

This image shows the successful prediction output of the machine learning model. A gun has been detected in the image, clearly labeled by a bounding box along with a prediction confidence score. The object is correctly recognized as a weapon, showcasing that the model is functioning as intended for identifying firearms.

Figure 15. Prediction Of Military Weapons

The Fig.20. shows a military aircraft. If this was part of a defense object detection dataset, the model maybe identifying or logging it for surveillance purposes. However, it's unclear if this was classified as an unauthorized object. If the aircraft was labeled or boxed, it may indicate the model's capability to detect large-scale military equipment.

Figure 16. Displays Explosives Being Detected By The System

Figure 16 displays missiles being detected in the frame. The machine learning model identifies them, demonstrating its broader scope to detect advanced military-grade weaponry. The system can recognize missile shapes and flag them as threats in relevant surveillance scenarios.

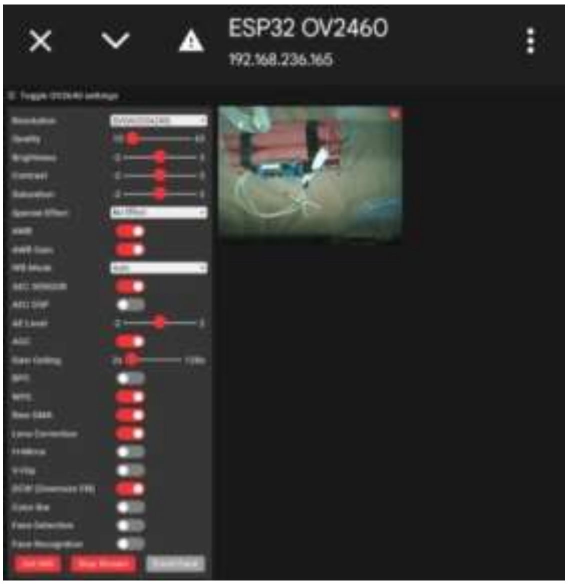

Figure 17. ESP32 Cam Live Feed

The Fig.17. shows that the ESP32 CAM is connected with devices such as phone or laptops like that. This is how the vision process is done. When this the operator can manually see via this and if they saw any bomb they can diffuse via gripper also we implemented the ml in this so it can also automatically detect when if it see any bomb and sends the email which it it detects

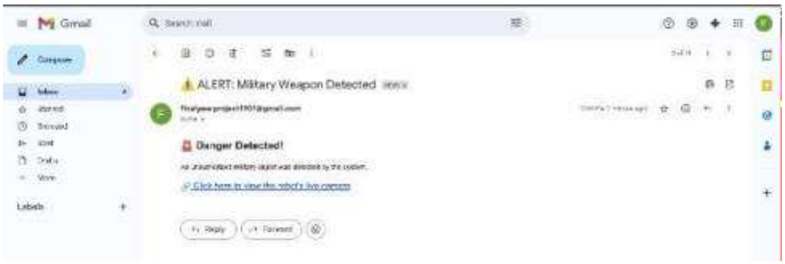

Figure 18. E-mail Alert When Detected a Landmine or Bomb

The Fig.18. And Fig.19. shows that the email notification automatically sent by the system upon detection of an unauthorized object such as a weapon. The email includes evidence such as the detected image and the time of occurrence, ensuring authorities receive timely and actionable alerts to prevent potential threats in restricted. It also shares the exact location of the explosives present to the user.

Figure 19. E-mail Of GPS Sharing The Location Of The Explosive

7 Conclusion

The developed bomb detection and disposal robot presents an integrated and intelligent solution for enhancing safety in hazardous environments. By combining metal detection, toxic gas monitoring, deep learning-based weapon recognition, IoT-enabled cloud communication, GPS tracking, and RF-based remote control within a single platform, the system addresses multiple operational challenges simultaneously. The robotic gripper mechanism enables safe handling and neutralization of explosive threats, while real-time video streaming and automated email alerts ensure continuous situational awareness. The classification of gas levels into Safe, Warning, and Dangerous categories further strengthens environmental monitoring and early hazard detection. Unlike conventional systems that focus on isolated functionalities, this approach unifies detection, monitoring, communication, and disposal into a structured multi-layered architecture. The design reduces human exposure to risk, improves response time, and enhances operational efficiency. With its modular structure and scalable framework, the system holds strong potential for deployment in defense operations, disaster response, industrial safety monitoring, and public security applications, while also providing a foundation for future advancements in autonomous robotic threat management.

8 Reference

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