iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.70816

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Defence Rover for Enhanced Surveillance and Threat Detection in High-Risk Zones

Sujal Shivatare[1], Rohan Mane[2], Uddhav Rodge[3], Kaustubh Shivneker[4], Prof. Nita Dimble[5]
Navsahyadri education society's group of institutions, Pune

Abstract: This paper presents the design and development of a defence rover aimed at enhancing surveillance and threat detection in high-risk environments. The rover is equipped with ultrasonic sensors for obstacle detection and GPS modules for location tracking. It can detect human presence and identify hazardous objects while employing countermeasures like frequency blockers to evade external detection. The system is powered by a Raspberry Pi, which handles sensor data processing and communication. This paper details the system's architecture, including hardware integration, secure communication proto cols, and the methodology for real-time object detection. Field tests demonstrate the rover's ability to operate in challenging environments and accurately identify potential threats. Future improvements will focus on expanding communication range, enhancing detection accuracy, and increasing system reliability.
Keywords: Defence rover, Obstacle detection, GPS tracking, Human detection, Hazard identification, Surveillance systems, Raspberry Pi, Secure communication, Threat identification.

I. INTRODUCTION

Modern surveillance and defence systems must address increasing threats across diverse environments. Traditional surveillance methods often rely on manual operation, which limits coverage and poses risks to human operators. To mitigate these challenges, remotely operated defence rovers equipped with advanced sensing and communication technologies offer a more efficient and safer solution for real-time monitoring and threat detection.

This paper presents a defence rover equipped with ultrasonic sensors for obstacle detection and GPS modules for precise location tracking. The rover can identify human presence, detect hazardous objects, and deploy frequency blocking countermeasures to evade external surveillance systems. A Raspberry Pi is used as the central processing unit, responsible for managing sensor data, decision-making, and communication with external systems.

The primary goal of this system is to provide continuous monitoring while ensuring secure communication and operational reliability. This paper discusses the rover's architecture, implementation process, testing procedures, and future improvements to enhance system performance in real-world applications.

II. LITERATURE REVIEW

The field of robotics and intelligent autonomous systems has evolved significantly, particularly in the defence and surveillance domains. A review of related works and advancements is summarized below.

A. *Sensor-based Robotics and Control System*

D. Ibrahim in his foundational work [1] elaborated on the integration of microcontrollers in applied digital control systems, laying the groundwork for responsive and modular robotic architectures. His insights provide a basis for interfacing various sensors (like ultrasonic, gas, and accelerometer) with embedded systems to enable reactive behaviour in real time environments.

J. A. Angelo's guide to robotics [2] presents a comprehensive reference to robotic technology, highlighting its significance in industrial, defence, and safety applications. Hiswork underscores the importance of reliable sensor inputs and adaptive algorithms in ensuring consistent performance in varied conditions.

B. *Surveillance Robots for Security Application*

Multiple studies have focused on deploying mobile robots for surveillance in hostile or remote environments. Meghana et al. [3] implemented a surveillance robot equipped with IR and gas sensors for outdoor security. Their design emphasized obstacle detection and fire/smoke alerts, which aligns with the proposed system's gas detection and ultrasonic modules.

Prakash and Walambe [4] demonstrated the use of the Robot Operating System (ROS) in military surveillance, integrating wireless video transmission and remote control for real-time threat assessment. Their approach contributes significantly to the evolution of vision-based navigation in rugged terrains.
T. Akilan et al. [5] developed a surveillance robot for hazardous environments using IoT technology. Their robot could detect obstacles and monitor environmental parameters, similar to the gas, metal, and tilt detection modules incorporated in our system. Their work highlights the increasing role of IoT in real-time defence monitoring.

C. Human-Robot Interaction and Control

Sharma et al. [6] explored Android-based Bluetooth control of robots, which supports our decision to use the HC 05 Bluetooth module for wireless operation. Their results confirm the feasibility and ease of using smartphones for robot navigation, particularly in field deployments.
Xiaolu et al. [7] introduced a smartphone-based robot control system and emphasized the potential of mobile computing platforms to facilitate interactive robot control interfaces. Their research validates the use of mobile apps in human-robot interaction and expands on potential improvements using sensor feedback integration.

D. Multi-Agent and Tactical Robotics

Giachetti and Rojas [8] simulated coordination strategies for human-robot teams in military contexts. Their work discusses operational constraints, task synchronization, and command latency—insights that are crucial when extending the single rover design into a coordinated fleet for tactical missions.

E. Summary

The reviewed literature collectively emphasizes the effectiveness of sensor-based autonomous navigation, Bluetooth enabled remote control, face detection for access control, and robust control systems in defence-related robotic applications. The proposed rover integrates these features with low-cost components, targeting real-time deployment in sensitive environments such as border areas or disaster zones.

III. PROBLEM STATEMENT

Traditional surveillance systems face multiple challenges in delivering effective threat detection, environmental aware ness, and secure communication in high-risk environments. The primary issues include:

1) Limited ability to detect obstacles and unknown objects in real time, especially in dynamic environments
2) Lack of efficient mechanisms to identify hazardous conditions such as smoke or gas leaks during patrol missions
3) Inability to recognize human presence or intruders autonomously using camera-based vision systems
4) Difficulty in maintaining reliable short-range wireless control for testing and override scenarios
5) Challenges in detecting tilts, falls, or instability during navigation over uneven terrain.
6) Inadequate detection of hidden or buried metallic objects in the environment

This project addresses these challenges by designing a multi-sensor defence rover equipped with ultrasonic, gas, vision, accelerometer, wireless, and metal detection systems. These technologies enhance autonomous threat detection, improve situational awareness, and ensure secure operational control, thereby reducing human risk in hazardous defence applications

IV. PROPOSED METHODOLOGY

The development of the AI-Driven Defence Search and Safety Rover follows a multi-layered engineering strategy, integrating real-time environmental awareness, embedded intelligence, and secure communication. This section elaborates on the key components, system design, communication protocol, and evaluation process that together ensure effective performance in defence scenarios.

A. Hardware Components

The rover integrates multiple sensor modules and control systems to enhance its threat detection and autonomous decision-making capabilities. Major hardware features include:

1) Raspberry Pi: Serves as the central control unit that collects sensor data, performs face recognition, and handles wireless communication with the command centre. Its support for Python and GPIO interfacing enables rapid deployment of sensor-driven logic.

2) Ultrasonic Sensors: These sensors continuously scan the front and sides of the rover to detect obstacles based on sound wave reflection. The data helps the robot avoid collisions and navigate around objects. [5]
3) MQ-3 Gas Sensor: The rover is equipped with an MQ 3 sensor to detect flammable gases or smoke in the surroundings. It enables early warning in the presence of fire, fuel leaks, or toxic vapours during patrols.
4) Camera Module: The camera module captures live footage for surveillance and is integrated with face recognition algorithms to detect unauthorized individuals or personnel in restricted zones.
5) ADXL345 Accelerometer Sensor: The accelerometer identifies tilt angles and orientation changes. It helps determine if the robot has flipped, fallen, or is climbing uneven terrain, enhancing situational feedback.
6) HC-05 Bluetooth Module: Enables manual control of the rover through a paired smartphone or controller. It provides a fall back or override system in case of AI malfunction or during manual testing phases. [6]
7) Metal Detector: Used for detecting hidden or buried metallic objects, which can indicate landmines or enemy devices. It enhances the robot's search-and-detect capabilities in sensitive areas.

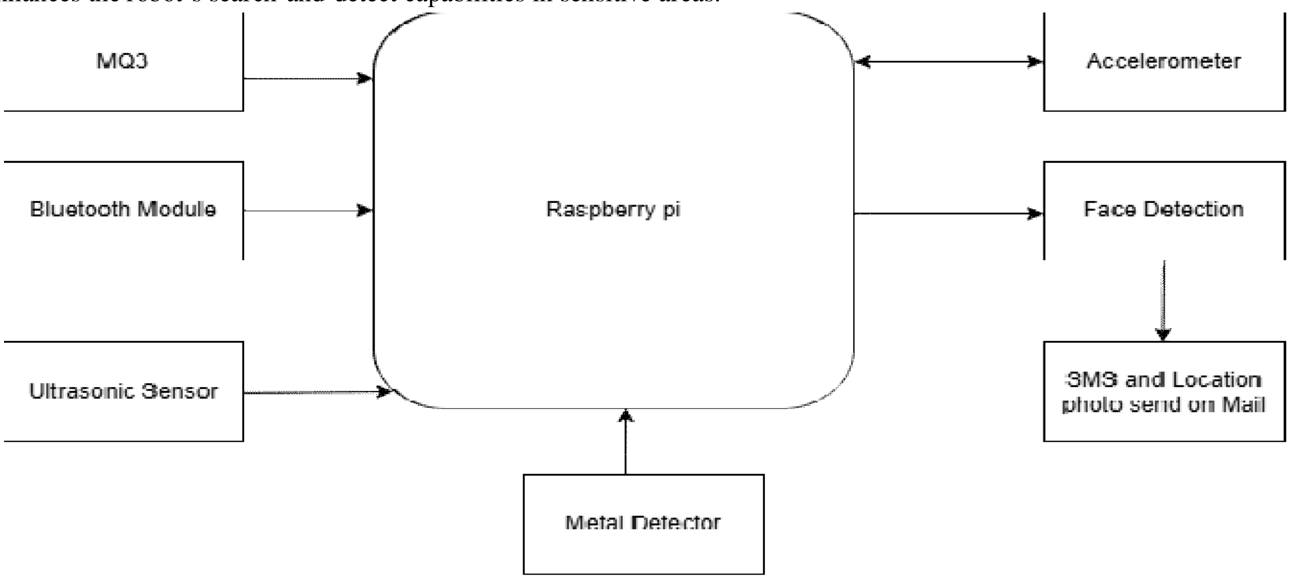


Fig. 1 Components of System Architecture

B. System Architecture

The rover features a modular and interconnected system. All hardware components are controlled via a central software algorithm hosted on the Raspberry Pi.

1) Real-time data from sensors (ultrasonic, gas, accelerometer, camera, and metal detector) are continuously streamed into the processing unit.
2) Upon detecting a potential hazard—such as a nearby object, smoke, or unauthorized face—the Raspberry Pi processes the signal and initiates actions like stopping, alerting the base, or rerouting.
3) Secure Bluetooth-based manual control is available via the HC-05 module in test or override mode.
4) All video and telemetry data are encrypted before being transmitted to the base station using secure protocols. Figure 3 displays the full prototype model including all integrated components.

C. Communication Protocol

The defence rover implements a reliable and efficient communication protocol to maintain uninterrupted contact with the base control system. The main features include:

1) Bluetooth-Based Communication: A robust HC-05 Bluetooth module is used for wireless data transmission between the rover and the operator within a defined range. It supports serial communication, making it suitable for real-time command and control scenarios. [7]
2) Data Optimization: Sensor readings and image frames are processed and optimized using lightweight data formats such as JSON and compressed image encodings (e.g., JPEG) to reduce transmission size. This enables efficient data exchange even with bandwidth limitations, while ensuring critical details for decision-making are preserved.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

3) Fail-Safe Mechanism: The system continuously monitors the communication link status. In case of signal drop or command loss, the rover activates a fallback protocol—halting operations or returning to the origin based on the last known command—to avoid mission failure or unintended behaviour

D. *System Workflow*

The functional workflow of the defence rover is structured to leverage all on board sensors and modules to ensure accurate threat detection, real-time monitoring, and safe operation:

1) Initialization: Upon activation, the Raspberry Pi initializes all connected sensors including the ultrasonic sensor, gas sensor (MQ-3), camera module, ADXL345 accelerometer, and metal detector.
2) Obstacle Detection: The ultrasonic sensor continuously scans the surrounding area for obstacles. If an object is detected within a predefined range, the rover pauses or reroutes to avoid collision.
3) Smoke Detection: The MQ-3 sensor monitors for the presence of smoke or harmful gases. If detected, the rover alerts the control centre and can log the location for future investigation.
4) Face Recognition: The camera module streams live footage and executes a face recognition algorithm to identify authorized or unauthorized individuals. Any unknown face is flagged and logged for manual verification.
5) Robot Tilt Detection: The ADXL345 accelerometer checks the rover's orientation. If abnormal tilting or rollover is detected, the rover either stops or alerts the operator to prevent mechanical failure.
6) Metal Detection: A metal detection module scans the ground for buried or hidden metallic objects, which could indicate landmines or suspicious hardware. The rover logs the GPS position and halts for operator review.
7) Bluetooth Communication: Data from all sensors and modules is sent to the control system via the HC-05 Bluetooth module, allowing real-time monitoring and remote control within operational range.
8) Operator Override: The operator can override autonomous actions, issue manual commands, or shut down the system in emergencies. A mobile app or computer interface is used for control and live feedback.

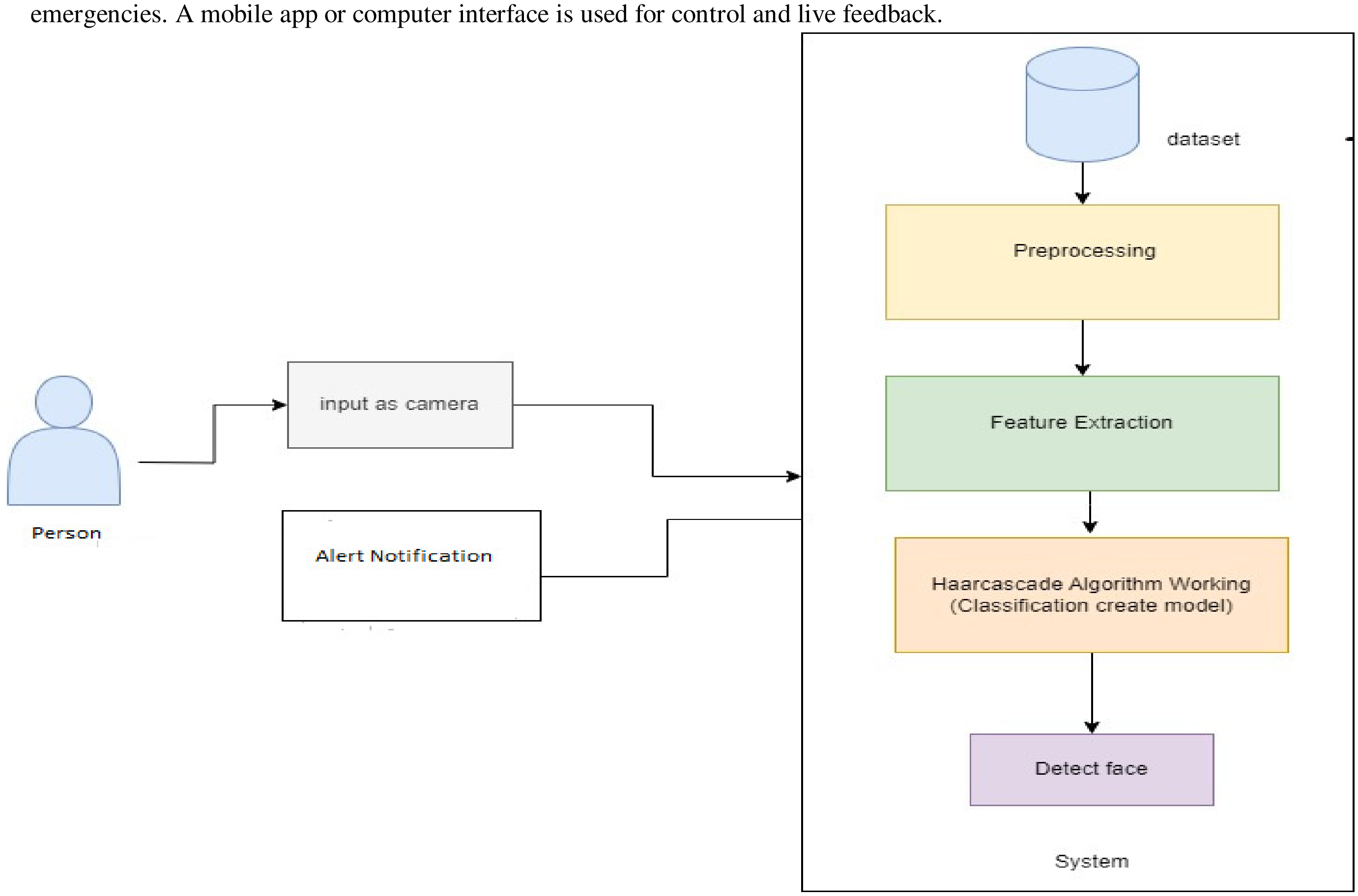


Fig. 2 Face Detection System Architecture

E. Testing and Evaluation

To ensure the operational reliability and accuracy of the defence rover, all core modules undergo rigorous testing under controlled and semi-realistic field conditions. Evaluation focuses on functional correctness, environmental adaptability, and user control.

1) Obstacle Detection Accuracy: The ultrasonic sensor is tested with various objects at different heights and distances to assess its ability to detect obstacles and trigger rerouting logic. Evaluation includes indoor and outdoor environments with static and moving objects.
2) Smoke Detection Sensitivity: The MQ-3 gas sensor is evaluated by exposing it to different concentrations of smoke and alcohol vapours. The system is monitored for timely alerts and false positives. Performance is calibrated against safety thresholds for industrial and field conditions
3) Face Recognition Precision: The camera module's facial recognition system is tested using datasets of known and unknown individuals under different lighting conditions and angles. Metrics include recognition accuracy, pro cessing time, and false match rates. [5]
4) Bluetooth Communication Range and Stability: The HC-05 module is tested for effective communication range, command response time, and resilience against interference. The system is observed for connection dropouts and signal delay across different terrains.
5) Tilt Detection Responsiveness: The ADXL345 accelerometer sensor is tested by intentionally tilting the robot in multiple directions and measuring its ability to detect abnormal angles or falls. The timing and reliability of safety-triggered actions are also recorded.
6) Metal Detection Reliability: The metal detection module is assessed by burying and placing metallic objects of varying size and depth. The system's ability to detect, alert, and log the location is carefully analysed.

These tests ensure that each sensor and subsystem functions correctly and that the overall system is robust enough to be deployed in challenging real-world defence or disaster scenarios.

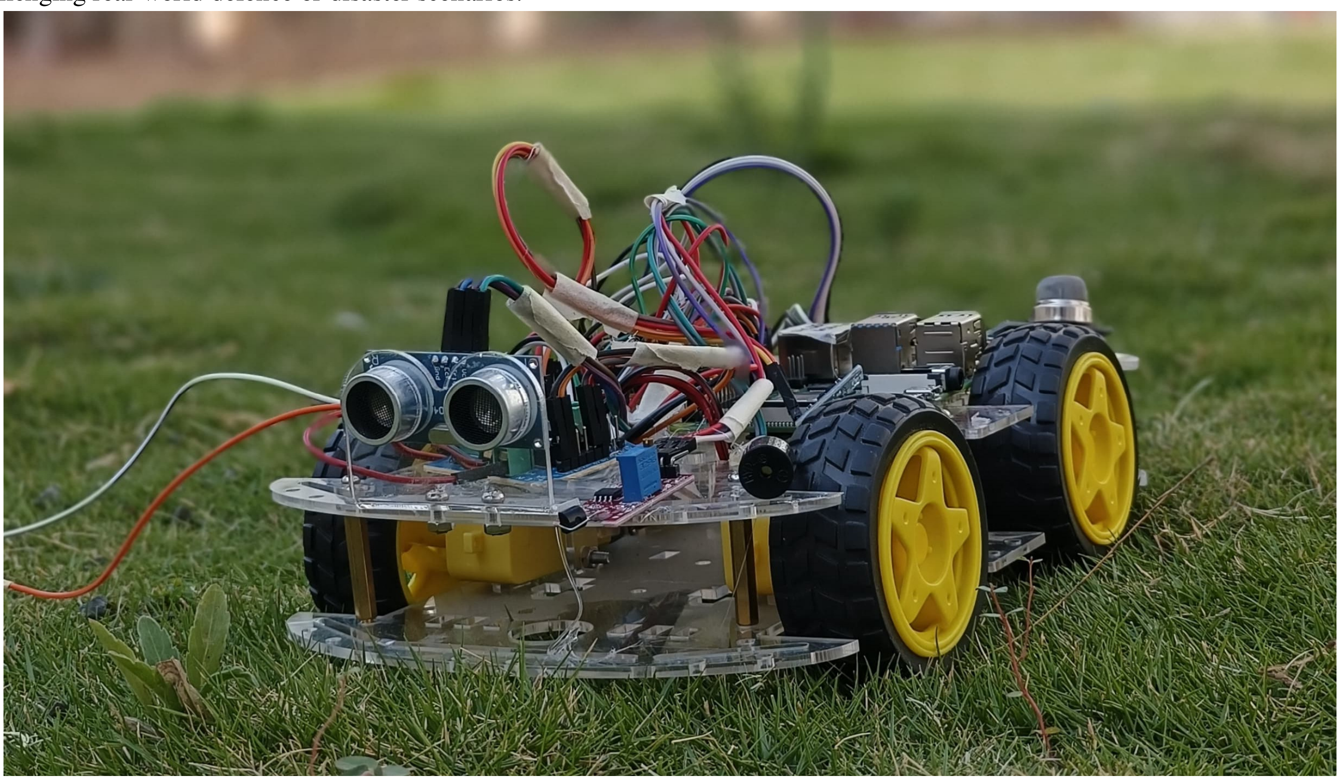


Fig.3 Final Model of Defence Rover

V. CONCLUSIONS

The defence rover presented in this paper offers a reliable and efficient solution for enhancing surveillance and threat detection in critical environments. By integrating key hardware components such as the Raspberry Pi, ultrasonic sensors, GPS module, gas sensor, and frequency blocker, the system provides real-time monitoring and secure data transmission.

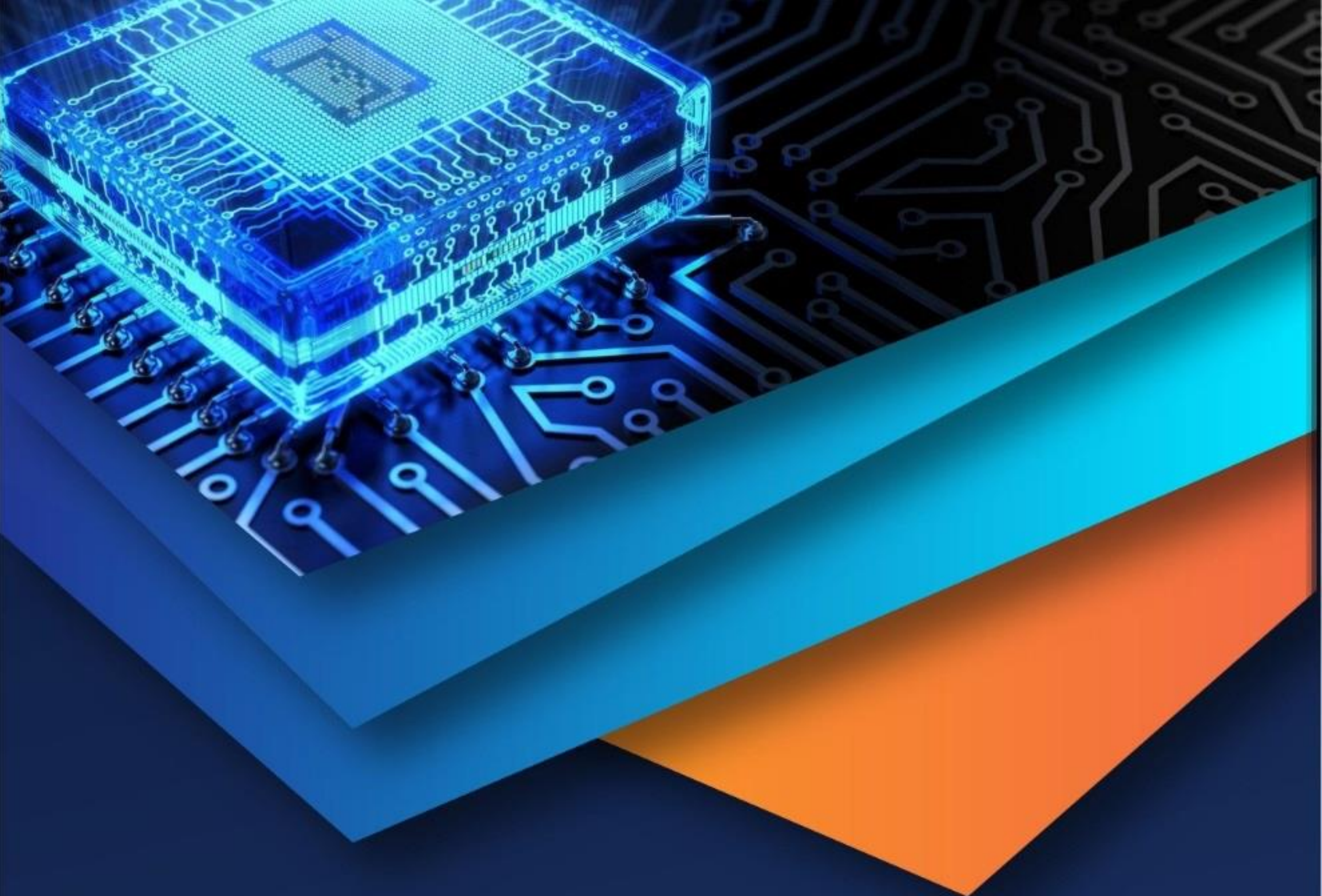
The proposed system is capable of detecting physical obstacles, tracking location, identifying hazardous gases, and preventing external detection through frequency blocking. Secure communication protocols, including Transport Layer Security (TLS), ensure data integrity and confidentiality during information exchange with the control station. The design emphasizes modularity, allowing future expansions and upgrades without compromising operational efficiency.

Future developments will focus on improving detection accuracy, extending communication range, and optimizing power consumption. In addition, enhancing environmental adaptability and increasing the robustness of the system will further strengthen its operational effectiveness in real world scenarios. Overall, this work contributes to the field of advanced surveillance by providing a comprehensive and adaptable defence rover capable of operating in high-risk environments while ensuring reliable communication and threat mitigation.

Overall, this work contributes to the field of advanced surveillance by providing a comprehensive and adaptable defence rover capable of operating in high-risk environments while ensuring reliable communication and threat mitigation.

REFERENCES

[1] D. Ibrahim, Microcontroller Based Applied Digital Control. England: John Wiley & Sons, Ltd, 2006.
[2] J. A. Angelo, Robotics: A Reference Guide to the New Technology. Libraries Unlimited, 2007.
[3] S. Meghana et al., “Design and implementation of surveillance robot for outdoor security,” in 2017 IEEE RTEICT Conference, Bangalore, India, 2017.
[4] A. Prakash and R.Walambe, “Military surveillance robot implementation signors,” in 2018 IEEE PuneCon, Pune, India, 2018.
[5] A. Sharma et al., “Android phone controlled robot using Bluetooth,” IJEEE, vol. 7, pp. 443–448, 2014.
[6] Xiaolu et al., “Robot control design based on smartphone,” in CCDC 2013, 25th Chinese Conference. IEEE, 2013.
[7] R. E. Giachetti and J. A. Rojas, “Simulating coordination of human robot teams for military operations,” in IIE Annual Conference, 2007.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY